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THE

MINING INSTITUTE

OF SCOTLAND.

TRANSACTIONS

Vol. XI.—1889-90.

HAMILTON:
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IA STATE

THE MINING INSTITUTE OF SCOTLAND.

TWELFTH ANNUAL MEETING,

HELD IN THE

HALL OF THE INSTITUTE, HAMILTON,

25th April, 1889.

JOHN M. RONALDSON, Esq., President, in the Chair.

The minutes of the last General Meeting were read by the Secretary and confirmed.

COUNCIL'S REPORT.

The SECRETARY read the report of the Council as follows:—

The Council have the pleasure, in submitting the Eleventh Annual Report, of stating that the progress which has characterized the Institute in each of the past years of its existence still continues to be maintained, and the membership is still on the increase.

At the date of last Annual Meeting there were on the Roll,			487
Additions during the year, ...		50	
Resignations, ...	12		
Deaths, ...	6		
Names struck off on account of non-payment of Subscription, ...	16		
	—	34	
Net increase, ...		—	16
Making a total membership at this date of			503

The position the Institute has now attained in point of numbers is gratifying, and is evidence of the quickened interest that is taken over the country in the advancement of the science and art of mining.

Along with this gratifying increase in membership there has not been a proportionate increase in personal attendance of members at the General Meetings of the Institute. The membership is drawn from all parts of the country, and it is not to be expected that those at a distance from the place of meeting can attend with any degree of regularity; but the Council, although sensible of the great interest taken in the proceedings of the Institute, think there is room for improvement in the matter of attendance by many who reside within a moderate distance of the headquarters of the Institute.

About the beginning of the session a Committee was appointed to take cognizance of the new blasting agents termed "Flameless Explosives," and to make experiments with them when opportunity offered. Some experiments of a practical kind were made by the Committee with Roburite, and their report is printed in the Transactions.

Another Committee was appointed to investigate the subject of Coal Cleaning, and to report on the various methods practised in this country. The work of the Committee will entail considerable expense, but it is expected that their report will be of great value to the Institute.

The papers and relative discussions contained in the Transactions of the year are not behind those of former years in respect of the fresh and useful information they yield. The value of the papers would be enhanced if members from a distance would contribute to the discussions by letter to a greater extent than is done at present.

The following is a list of the papers which, with the discussions thereon, have been printed in the Transactions and circulated among the members:—

President's Address.
Scotch Mining Legislation.
Stauss's Cage-easing Apparatus.
Committee's Report on Experiments with Roburite.

Description of Newbattle and Arniston Collieries.
Haulage by Self-Acting Endless Chains.
The Air of Coal Mines.
Edison & Swan Co.'s Electric Safety Lamp.
Longwall Working in the Edge Seams at Niddrie Collieries, Mid-Lothian.
Notes on Coal-Washing Machines.
Air-Vessels.

The Annual Excursion to Newbattle and Arniston Collieries was largely taken advantage of by members from all parts of the country.

The following is a list of the donations received during the year :—

DONOR.	DONATION.
FERD. J. ROWAN, ...	... Paper on the Estimation of the Calorific Value of Solid and Liquid Fuels. Paper on Chimney Draught and Forced Combustion ; Two Copies. Paper on Evaporation by Multiple Effect ; Two Copies. Paper on Flame ; Two Copies—*All by the Donor.*
MASKELL W. PEACE, ...	... "The Coal Mines Regulation Act, 1887." —*By the Donor.*
RALPH MOORE, ...	.. Mining and Mineral Statistics, 1887.
SECRETARY OF STATE, ...	... Reports of the Inspectors of Mines, 1887.
HERMANN SPRENGEL, Dr. Phil.,	... Pamphlet on a new class of Explosives. —*By the Donor.*
J. M. RONALDSON, ...	... Reports of the Inspectors of Mines, 1887. Mining and Mineral Statistics, 1887.
C. M. IRVINE, ...	... The Collieries, Coalfields, and Minerals of New South Wales, by Alf. J. G. Swinney ; 1884. Pamphlet on Colliery Managers, their Training and Duties, by J. P. Martin ; 1878. Mineral Statistics of the United Kingdom, 1866-67-68-69-70-79-80-81-82. Report of Trial for Infringement of Hot Blast Patent ; 1843.

DONOR.	DONATION.
A. R. SAWYER, ...	Miscellaneous Accidents in Mines.—*By the Donor.*
G. C. GREENWELL, ...	A Glossary of Terms used in the Coal Trade.—*By the Donor.*
JAMES BARROWMAN, ...	A Lecture on Some Chapters in the History of Scotch Mining and Miners; Two Copies.—*By the Donor.*

There is appended also a list of the additions to the Library since the last issue of the catalogue.

There have been 15 Meetings of the Council during the session.

In addition to the Transactions and current Mining Papers got in exchange the following Books and Pamphlets have been added to the Library during the year 1888-89 :—

I. BOOKS.

Miscellaneous Accidents in Mines, 1889, ... *A. R. Sawyer.*
British Mining: a Treatise on the Metalliferous Mines of the United Kingdom, 1887, ... *Robert Hunt.*
Manual of the Coal Mines Regulation Act, 1887, ... *John C. Chisholm.*
Coal Mines Regulation Act, 1887, and Truck Acts, 1831 and 1887, ... *Maskell W. Peace.*
Manual of Geology, 1879, ... *James D. Dana.*
Elements of Metallurgy, 1887, ... *J. Arthur Phillips* and *H. Bauerman.*
Mine Foreman's Handbook of Practical and Theoretical Information, 1887, ... *Robert Mauchline.*
Minerals of New South Wales, 1888, ... *Professor Liversidge.*
A Glossary of Terms used in the Coal Trade of Northumberland and Durham, 1888, ... *G. C. Greenwell.*
The Collieries, Coalfields, and Minerals of New South Wales, Australia, 1884, ... *Alfred J. C. Swinney.*
Report of the Trial for Infringement of the Hot Blast Patent, 1843—James Beaumont Neilson *v.* William Baird & Coy. ... ...
Chapters on the Mineralogy of Scotland, 1876, .. *Professor Heddle.*
Reports of the Inspectors of Mines, year 1887.... ...

II. PAMPHLETS.

An Essay on Colliery Managers: their Training and Duties, 1878, ... *Tom P. Martin.*
Notes on Safety Lamps, 1883, ... *Joseph Dickinson.*
Cleaves' Cove, Dalry, Ayrshire: its Exploration and History, 1883, ... *John Smith.*
Geological Observations in the Parish of East Kilbride, Lanarkshire, 1884, ... *Andrew Patton.*
Craignethan and its Vicinity, 1878, ... *Dr. John R. S. Hunter.*
How to make a Geological Map, 1883, ... *Horace B. Woodward.*
Fossiliferous Rocks of Borrowstounness, 1883, ... *H. M. Caddell.*
On the altered Rocks of the Western Islands of Scotland and the North Western and Central Highlands, 1861, ... *Sir Roderick J. Murchison* and *Archd. Geikie.*
The Carboniferous Formation of Scotland, 1879, ... *James Geikie.*
Lower Carboniferous Rocks of the Fifeshire Coast, 1860, ... *Rev. Thos. Brown.*
On Basalt and its Effects, 1878, ... *G. C. Greenwell.*
On New Minerals found in Scotland, 1879, ... *Professor Heddle.*
Notes on the more Recent Discoveries in the Cresswell Caves, 1880, ... *Rev. J. M. Mello.*
Notes illustrative of the Geology of part of the Shores of East Lothian and Berwickshire, 1852, ... *James P. Fraser.*
On the Geology of Coal and Coal Deposits in the British Islands, 1874, ... *R. Etheridge.*
Explosions in Mines, 1879, ... *George Wild.*
The Method adopted in Sinking through Quicksand at the Bamfurlong Collieries, Wigan, 1880, ... *Walter Topping.*
Mining, Quarrying, and Metallurgical Processes and Products, 1851, ... *Sir Henry T. De La Beche.*
Sprengel on a New Class of Explosives, 1873, ...
On the Estimation of the Calorific Value of Solid and Liquid Fuels, 1888, ... *Fred. J. Rowan.*
MS. Corfield *v.* Evans: a Derbyshire Colliery Case, 1886.
Return of the Quantities of Coal, &c., raised in each of the Mining Counties of the United Kingdom for the years 1854 and 1855 respectively. .. ...
Reports received from Her Majesty's Secretaries of Embassy and Legation respecting Coal, 1866. ...
British Iron Trade Statistics for the half year to 30th June, 1888. ... ...
Report from Lyell and Faraday on the Subject of the Explosion at Haswell Collieries, and on the means for preventing similar accidents, 1844. ... ...

Report addressed to the United Committee of the Coal Trade by the Special Committee appointed to take into consideration the report from Messrs Lyell and Faraday on the subject of the Explosion at Haswell Collieries, and on the means for preventing similar accidents, 1845.	
Acts of Parliament relating to Coal and Mining, 1710-1887.	
Some Chapters in the History of Scotch Mining and Miners, 1889, ...	*James Barrowman.*
The Miners of Scotland, 1888, ...	*Robert Haddow.*
Scientific Papers of Sir W. Siemens, 3 vols., 1889. ...	
Some Notes on Chimney Draught and Forced Combustion, 1888, ...	*F. J. Rowan.*
On Evaporation by multiple effect, 1889, ...	*F. J. Rowan.*
On Flame, 1889, ...	*F. J. Rowan.*

The PRESIDENT said he thought they had had a very gratifying report of the proceedings during the year so far as membership was concerned, and he supposed financially also, because the one hung on the other; but he was sorry there was a falling off in the attendance at the meetings. He thought that was a very important matter also, and he hoped that what Mr Barrowman had called attention to in the report would do something to bring out more members to help them with their views on the papers laid before them. He proposed that they should adopt the report.

This was unanimously agreed to.

FINANCIAL REPORT.

The SECRETARY read the following Abstract of Accounts for the past year, duly audited :—

ABSTRACT of ACCOUNTS for Session 1888-89.

Receipts.

To Balance from 1887-88,				£227	15	9½
,, 173 Members' Subscriptions at 21s,				181	13	0
,, 5	Do.	do.	20s 6d,	5	2	6
,, 1	Do.	do.	20s,	1	0	0
,, 279	Do.	do.	10s 6d,	146	9	6
,, 1	Do.	do.	10s,	0	10	0
,, 18	Do.	do. arrears,	21s,	18	18	0
,, 9	Do.	do. ,,	10s 6d,	4	14	6
,, 4	Do.	do. 1889-90,	21s,	4	4	0
,, 1	Do.	do. ,,	10s 6d,	0	10	6
,, 1 Life Member's Subscription,				10	10	0
,, Received for Transactions, Titles, &c.,				15	3	11
,, Do. Rents of Hall,				8	0	6
,, Do. Advertisements,				6	6	0
,, Do. Bank Interest,				5	3	0
				£636	1	2½

Payments.

By Printing and Stationery,				£201	6	6
,, Books, Maps, and Bookbinding,				29	11	4
,, Rents of Halls,				15	11	3
,, Gas and Assessments,				2	12	2
,, Stamps, Carriages, &c.,				8	4	0
,, Committee on Coal Cleaning,				30	0	0
,, Sundry Payments,				4	1	2
,, Salaries,				79	12	0
,, Cleaning,				6	0	0
,, Balance in Bank,	£254	2	6			
,, Do. Treasurer's hands,	5	0	3½			
				259	2	9½
				£636	1	2½

4th April, 1889.—Examined, compared with vouchers, and found correct.

DAVID FERGUSON,
J. B. DALZELL, } AUDITORS.

The PRESIDENT said they were still coming to the front with their surplus, which was certainly very gratifying.

ELECTION OF OFFICE-BEARERS.

The PRESIDENT announced that the following gentlemen who had been nominated at last general meeting as office-bearers for the ensuing year were now duly elected :—

President.

JOHN M. RONALDSON, 44 Athole Gardens, Glasgow.

Vice-Presidents.

JAMES SMART, Balgreen, Hamilton.
JAMES HASTIE, Greenfield Colliery, Hamilton.
DAVID COWAN, Carron, Falkirk.
J. B. ATKINSON, 10 Foremount Terrace, Glasgow.

Councillors.

THOMAS ARNOTT, Clyde Cottage, Tollcross.
JAMES T. FORGIE, Bothwell Collieries, Bothwell.
JAMES GILCHRIST, Earnock Colliery, Hamilton.
ALEXANDER M. GRANT, Townholm, Kilmarnock.
JAMES HAMILTON, 208 St. Vincent Street, Glasgow.
JOHN HOGG, North Motherwell Colliery, Motherwell.
HUGH JOHNSTONE, 2 Boswell Terrace, Glasgow.
ROBERT M'LAREN, Crofthill Place, Uddingston.
DAVID M. MOWAT, Summerlee Iron Works, Coatbridge.
JAMES PRENTICE, Stanrigg Collieries, Airdrie.
MICHAEL ROSS, Eddlewood Colliery, Hamilton.
WALLACE THORNEYCROFT, Merryton Colliery, Hamilton.

The following were elected by ballot as ordinary members :—

D. R. BRYSON, 69 Buchanan Street, Glasgow.
ROBERT WILSON, Anchorage, Bothwell.
D. K. HARROWER, Bo'ness.
GEORGE CANNING, Springbank Colliery, Airdrie.
WILLIAM CASSELS, Springbank Colliery, Airdrie.
J. B. ATKINSON, 10 Foremount Terrace, Glasgow.
JAMES HUGH, Priory Lodge, Blantyre.
T. H. MOTTRAM, 5 West Garden Street, Glasgow.
FRED. W. MOORE, 9 Ibrox Place, Govan.
JOHN MENZIES, Gilmerton Colliery, Gilmerton.

The PRESIDENT, Mr J. M. Ronaldson, then delivered the following address :—

PRESIDENT'S ADDRESS.

GENTLEMEN,—In the name of the members of Council, I thank you for the honour conferred upon us by appointing us office-bearers of the Mining Institute of Scotland for another year. Speaking for myself, I can only say that during the past year my position as President has been altogether a pleasant one, supported as it has been by the other members of Council, by whom the routine work of the Institute has been so ably conducted. So far as numbers and the state of the finances are concerned, we have no reason to fear the future; but we must not forget that, while these are most important factors in securing success, they are not everything, and that, if we are to maintain the position we now hold, this must be by members contributing papers and taking part to as great an extent as possible in the discussions thereon. I am aware that in saying this I keep twanging at the same string that has been harped on so often before, but non-contributing members cannot be too often reminded that we are a self-supporting society, depending upon the voluntary contributions of members for the contents of the Transactions; and that the greater the number of those who take part in the discussions the more valuable will the Transactions be. I would like to see many more members who cannot attend the meetings and personally take part in the discussions, give vent to their opinions on the subjects brought under our notice by forwarding them in writing to the Secretary; and I think you will agree with me in saying that we have many able members whose opinions are seldom or never recorded.

Then as regards subjects for papers, these have been by no means exhausted. Mr Moore, when President, remarked—and what he said is worth repeating—that papers do not necessarily require to be long, that they should be well illustrated, and that practical details of pit work clearly explained would form valuable contributions to the Transactions. That which is familiar to one man, and may to him seem not worth writing about, might be entirely new to others; while a description of how some difficulty was overcome or detail worked out may bring out by discussion what was done by others in similar situations. Not one of us is too old to learn, or knows so much that he may not

learn more; and, if we are to keep abreast of the times in which we live, the oldest as well as the youngest of our members has no slight task before him in grasping with intelligence the many new inventions and appliances in mining and kindred industries.

I question if any large industry is so fenced round by legislative enactments as mining. A miner may not go down a pit until certain regulations have been complied with; and when down he may not visit his neighbour in his working place; while the paternal Government takes such an interest in his welfare that it will not, in many cases, allow him to smoke his pipe, thereby depriving the nation of the revenue that would be otherwise derived from the increased consumpt of the fragrant weed. The duties of the under officials are minutely detailed; while, in the event of any non-compliance with the requirements of the statute by any person whomsoever, the owner, agent, and manager is each held responsible unless he proves that he has done his utmost to enforce the observance of the law. While the necessity for some of these regulations by many persons is questioned, I think we will all agree that, as a whole, they are not uncalled for when we consider the danger to life and limb by which mining is attended. Whatever may have been the effect of Government interference in the working of mines, statistics prove that the risk of a workman losing his life is not now half so great as it was thirty years ago. As will be seen from the following table, on the average one life was lost per annum for every 245 persons employed during the ten years ending in 1860, while the average during the last eight years was one life lost per annum for every 516 persons employed.

Average number of persons employed per death per annum.

Years.	Explosions of Firedamp.	Falls of Roof and Sides.	In Shafts.	Miscellaneous. Underground.	Miscellaneous. Aboveground.	Total.
1851-60	1,008	653	1,161	2,074	4,872	245
1861-70	1,408	767	2,121	1,666	4,119	300
1871-80	1,795	1,069	3,557	2,535	5,369	425
1881-88	4,767	1,115	5,795	2,467	5,968	516

It will be seen that the improvement in the death rate from explosions and shaft accidents is very marked. The increased number of fatalities from miscellaneous underground accidents is accounted for by the extended use of haulage appliances with heavier hutches, and while the causes of these accidents demand careful investigation, what I desire to call special attention to is the comparatively small progress that has been made since the passing of the Coal Mines Regulation Act of 1872 in reducing the number of accidents by falls. Of the 40,055 deaths by accident in and about the mines in the kingdom worked under the Coal Mines Regulation Acts during last 38 years, 40·3 per cent. were caused by falls, 21·5 per cent. by explosions of firedamp, 14·3 per cent. happened in shafts, 16·7 per cent. were miscellaneous accidents underground, and 7·2 per cent. were miscellaneous surface accidents. After investigating hundreds of accidents by falls, I have not the least hesitation in affirming that the greater number of them ought not to have happened, and could have been prevented by ordinary precaution. One would naturally suppose that the mines in which the roof is bad would have most accidents by falls of roof, but the facts are otherwise, and it is in the mines with good and comparatively good roofs that the workmen are killed or injured by these falls. Where the roof is very bad, the keeping of it secure demands and receives immediate attention. There is no delay in setting props, and the miners do not object to have them set close to the working face. The keeping up of the roof, which would otherwise give way, being imperative, there is consequently no sparing of props or other support, and there is no space for a heavy fall to take place at the working face where the miner is most exposed to danger, so that under such circumstances serious accidents do not often happen. On the other hand, where the roof is comparatively good, too often propping is neglected, or imperfectly carried out. The miner somehow finds it impossible to fill his hutch or work at the face if a prop in any way interferes with his movements, or he cannot find time to set props so long as he has coals to fill his hutch, the officials do not insist upon systematic propping, and when a stone falls from some unseen "lipe" and causes an accident, it is put down as an

occurrence which no one could prevent. In many cases systematic propping is carried out, but the system is to support the roof some distance back from the face, and not actually above where the miner works. If it could always be known by examination when the roof does not require support, the system of setting props when thought necessary might do, but when the most experienced workman is unable to know this with certainty, and frequently gets maimed or killed by such accidents, it is not unreasonable to assert that props or other support should be set so that only a fixed minimum area of roof in all cases should be left unsupported at the working face. I am thoroughly convinced that until such a system is made compulsory, or adopted voluntarily in every mine, there is little prospect of reducing the number of these accidents. As regards the spragging of the working face, miners, as a rule, have a strange antipathy to setting sprags or holing props. The setting of these "gibs" costs nothing, and yet through neglect of this simple precaution many miners are crushed by the coal suddenly giving way.

In the draft bill to amend the Coal Mines Act of 1872, a rule was inserted to make it compulsory that props and holing sprags should not exceed six feet apart, but this rule was so altered in passing through the House that the system of propping and spragging is still left optional. I did what I could to get systematic propping incorporated in the present special Rules, although without success, but I hope to see the day when the all but universal haphazard style of guarding against the miners' worst enemy will give place to a more rational one.

I do not mean to say that in all our mines the security of the roof and working face is not properly attended to, but I am of opinion that, as a general rule, much more could be done than is being done to secure the safety of our miners at the working face. I would that I could say that Scotland was no worse than the average of the kingdom in this respect, but, on looking into the statistics, I find that last year exactly 50% of the deaths in Scotland were caused by falls. The percentage was much the same for several previous years, with the exception of the year 1887, when the Udston explosion happened.

According to the statute, the roof and the sides of every

travelling road and working place require to be made secure, and timber must be provided convenient to the miners who, by the Special Rules, require to keep their working place secure, while the firemen are bound to see that this is done. If, in spite of these regulations, many preventable accidents by falls do occur, there is evidently something at fault, and, while it is quite impossible to avoid all accidents by falls, I submit that a great deal might be done to reduce their number by never allowing more than a limited area of roof to be unsupported at the working face.

Possibly, some may think that I have spoken rather strongly on this subject, but what I have said is the result of strong conviction, based upon an experience of fourteen years in investigating accidents. My views may not be those of others, and I would like to see this matter of securing the roof and sides of the working face thoroughly discussed. If some of our members would give a detailed description of the manner in which they deal with the subject in actual practice, such contributions would be of great value.

Mr JAMES S. DIXON proposed a vote of thanks to the President for his address, which was heartily awarded.

The following paper, "On Recent Development in the Application of Electricity to Mining," was then read by Mr Fred. J. Rowan :—

ON RECENT DEVELOPMENT IN THE APPLICATION OF ELECTRICITY TO MINING.

By Fredk. J. Rowan, C.E.

The date of the author's former paper on this subject may be accepted as that of the commencement, in this country, of a keen interest in the introduction of electric appliances into mining operations other than signalling and lighting. How much influence the publication of that paper had in the matter we can scarcely estimate, but if it had served no other purpose than to direct the energy and skill of electrical engineers to so promising a field of work as mining undoubtedly is, it was certainly not fruitless or ill-timed. There is some reason to say that it had that effect, as Messrs Immisch and others have owned that it turned their attention seriously in that direction, and, moreover, one at least of the suggestions given in the paper was subsequently made the subject of application for a British patent.

The practical development in electrical methods of working in mines which has taken place during the last two years is not only interesting, but also of substantial value, and it shows a rapidly increasing confidence amongst mining men in the many advantages of this form of power transmission.

It is perhaps needless to say that in other directions there has also been great development in applications of electricity, and the wonderful versatility of this mode of applying energy is witnessed to by the varied character of these applications.

In connection with mining, the problem of a portable electric miners' lamp seems now to be within reasonable distance of a satisfactory solution, and advance has also been made in electric methods of shot firing, with an accompanying increase of safety.

Confining our attention more strictly to the transmission of power, we have instances of the introduction of electrical plant for (1) Pumping, (2) Winding, and (3) Haulage to record.

Pumping.—The larger installation at Trafalgar Collieries, mentioned in the former paper (Trans. Vol. viii., p. 276), as then in process of erection, naturally comes first. It may be remarked that the original plant introduced by Capt. W. Blanch Brain in 1882, which does the work of about 1½ horse power, and a second

set, started early in 1886, using about 2½ horse power, and working at about 800 yards from the surface (to which Mr Frank Brain referred in his note to the author quoted on page 276 of his former paper) have continued to work until the present time, "doing," according to Mr F. Brain,* "excellent service, removing small quantities of water from remote parts of abandoned workings, which, for safety, must be kept clear of accumulations of water." The third and largest set of electrical plant—started in May, 1887—took the place of a Hathorn-Davey water-power pump working in conjunction with a 7-inch Manchester Pearn pump, having 10-inch steam cylinders and 14-inch stroke, two tubular boilers underground supplying the steam. The motor and pump are shown on Plate I.

The electrically-driven pump is a double plunger pump, 9 inches diameter and 10 inches stroke, fixed 2200 yards from the generator, and 1650 yards from the bottom of the shaft. It has a spur wheel and pinion, geared six to one, and is driven by a leather link belt, driving from a pulley 14 inches diameter on the motor shaft to a 5ft. 4in. pulley on the spur pinion shaft. This causes the pump to make 25 double strokes while the motor is running at about 650 revolutions per minute; and at this speed the pump can deliver 120 gallons per minute with 300 feet lift. This is the maximum speed of the motor, which is one of Elwell-Parker's 12-inch machines, having an output of about 13,000, Watts, or rather over 17 H.-P.

The pump was constructed with care to avoid friction; the valves and passages are large, and large air-vessels are provided. The plungers are brass, well fitted, and the mains being 7 inches diameter, in consequence of the smallness of the quantity of water passing through them (about 100 to 120 gallons per minute) the loss by friction is said by Mr Brain to be under 14 per cent. The electrical cable ultimately employed is lead-covered in the shaft, where it is enclosed in wooden boxes. In the roadways it is supported upon earthenware insulators, placed about ten yards apart along the side of the road. The return cable is an old iron pit rope about 4 inches

* Proc. S. Wales Inst. Eng., Vol. xv., p. 363.

in circumference, and is fastened by staples to the props along the road. The generator, standing above-ground near the top of the shaft, is also an Elwell-Parker's 12-inch dynamo—maximum speed about 950 revolutions, and output 17,000, Watts. It is driven by belt from a 5ft. 11in. pulley on the engine shaft to a 12-inch pulley on the dynamo shaft.

The steam engine used is an old marine engine bought at an auction, so much worn that it indicated a loss of 5 H.-P. when running empty. It has a single cylinder 16 inches diameter, and 12 inches stroke, using steam of 35lbs. pressure. This engine stands in the same engine-house with the engine used for driving the dynamo for the smaller pumps. The engine-house and pumps are connected by telephones and bell signals, and the necessary meters are also in the engine-room.

Observations taken by Mr F. Brain when the pump was being driven at 25 strokes (112 gallons) per minute, showed :—

Indicated H.-P. of steam engine, ...	29·49 H.-P.
Speed of generator, ...	900 Revolutions.
E. M. F. at terminals of generator, ...	320 Volts.
Current, " "	43 Ampères.
Speed of motor, ...	650 Revolutions.
E. M. F. at terminals of motor, ...	260 Volts.
Current, " "	43 Ampères.
Actual H.-P. of water lifted, ...	10·36 H.-P.

The total loss of power—19·13 H.-P., shown by these figures—is apportioned as shown in the following figures, and the diagram on Plate II., which has been lent by Mr F. Brain.

Loss in Engine, ...	6·49 H.-P.,	or 22	per cent.
" Generator, ...	4·56 "	16	"
" Line, ...	3·45 "	11	"
" Motor, ...	3·00 "	10	"
" Pump, ...	1·63 "	6	"
	19·13 H.-P.,	or 65	per cent.

The actual proportion of power given off by the steam engine which is used to lift water is, therefore, in this case, 35 per cent.

The percentage of useful effect derived from the power at each step is thus shown (Plate III.) :—

Received by			Loss in			Useful Effect.
Generator,	23·00 H.-P.	...	Steam Engine,	22 %	...	78 %
Cables,	18·44 H.-P.	...	Generator,	20 %	...	80 %
Motor,	14·99 H.-P.	...	Cables,	20 %	...	80 %
Pump,	11·99 H.-P.	...	Motor,	20 %	...	80 %
Water,	10 36 H.-P.	...	Pump,	14 %	...	86 %

A third diagram (Plate IV.) was also prepared by Mr F. Brain to show a comparison between the power given off at the belt driving the dynamo and the actual work done, according to the following figures :—

H.-P. given off to Generator				23·00 H.-P.
Loss in Generator, ...	4·56 H.-P.,	or 20 %		55 %
„ Cables, ...	3·45	„ 15 %		
„ Motor, ...	3·00	„ 13 %		
„ Pump, ...	1·63	„ 7 %		

The proportion of power given off by the belt which was used to lift water is thus 45 per cent.

The following figures of first cost, and of cost of pumping, are vouched for by Mr Brain as accurate :—

Dynamo and motor, ...	£310
Insulated copper cable, ...	138
Return wire—iron rope, ...	25
Signal wire, ...	10
Insulators, ...	6
Steam engine (estimate), ...	140
Fixing and sundries, ...	15
	£644

The pump (costing £130) and pipes are not included, nor is fitting up the engine or laying the mains, as these are charges common to all systems of using power.

Cost of pumping 114 gallons per minute with above machinery through 1300 yards of 7-inch pipes, main rising 300 feet; one week's pumping, twenty-two hours per day :—

Engineers (half-time), ...	£1	8	0
Man underground (full-time), ...	2	9	0
Small coal consumed (say 36 tons at 1s), ...	1	16	0
Oil, waste, and sundries, ...	0	7	0
Interest on capital and depreciation (say 15 %), ...	1	17	0
	£7	17	0

Cost per H.-P. on water raised—·02 of a penny.
Cost per 1000 gals. of water raised—1·80 of a penny.

Mr Brain has stated that the cost of maintaining this electrical plant, compared with that which it supplanted, shows an economy of £470 per annum, but that this is an exceptionally favourable result on account of the disadvantageous conditions under which the former plant was worked.

The dynamo, when not used for pumping, is switched into circuit with the motor of a ventilating fan some 1200 yards underground, placed in a return air-way, and passing about 10,000 cubic feet of air per minute.

In the latter part of 1887, Messrs Locke & Co., of St. John's Colliery, Normanton, made trial of a small electrical pumping plant, using dynamo and motor of Immisch's manufacture, and supplying the pumps and piping themselves. Neither the steam engine nor pumps were specially designed for use with electrical plant, but the following results show a fair commercial return of useful work:—

Results of Trials with Pumps delivering 39 gallons per minute through a head of 530 feet = 6·3 horse-power in the Water.

Work Done.	Speed of Engine.	Volts on Dynamo.	Av'rage Ampères given out by Dynamo.	Electrical Horse-power given out by Dynamo.	Work Done in Cylinder of Engine.	Efficiency.	Loss in Cables. Resist'nce 29 Ohms, 800 Yards of 19 Sixteens.
					Horse-power.	Per cent.	Horse-power.
Pumps delivering 39 gallons per minute ...	86	171 173·5	47·5 47·5	10·9 11	14·2	$\frac{6·3}{14·2}=44·4$	0·88
Pumps running with the suction clack lids off and the column empty	86	134 128 127	28 28 26	5 4·82 4·45	6·3	—	0·305 0·305 0·265
Motor and first motion shaft only	88 86	111 105	20 20	2·96 2·8	4·8	—	0·156
Dynamo only, running on open circuit ..	86	—	—	—	1·715	—	—

In carrying out these trials, a single-cylinder horizontal engine was used. The diameter of the cylinder was fourteen inches and the stroke fifteen inches. The steam pressure was varied by a reducing valve according to the work required. The engine was an old girder engine, and during the test it was found that the slide valve nuts had shifted on the lower side of valve. The diagrams were thus defective, since the steam was admitted too late and cut off too soon at the bottom part of the stroke. This must have lowered the efficiency of the engine to some extent, and, of course, is against the net efficiency of the system. The power required to overcome the friction of the engine and dynamo without any load was 1·715 horse-power. The motor ran at a speed of about 650 revolutions per minute during the test, the pumps making eight revolutions. The gearing consisted of three transmissions. The first was a ten-inch cotton belt, the second a mortised pinion gearing into a cast-iron wheel, and the third a cast-iron pinion and a wheel on the crank shaft of the pumps. This complex system for reducing the speed of the motor was, of course, not the arrangement originally designed, but circumstances made it convenient to use gearing in this manner.

The pumps were made to the design of Mr Brown, the engineer of the colliery. They consisted of two separate differential pumps. Each had one six-inch ram and one four and a-half inch ram. They were coupled by cross-heads and connecting-rods to the main shaft, with the cranks at right angles. The suction was made only by the six-inch rams, but all the rams delivered water into the column. There were thus two suctions and four deliveries per revolution of the crank shaft, the pumps being equivalent to a four-throw pump with a four and a half inch ram. The division of the work done by the large rams was not by any means equal. Though to casual inspection the work done throughout a revolution seemed constant, an ammeter in circuit with the motor showed considerable fluctuations of current at regular periods. The difference of load thus experienced was as much as 25 per cent., and caused at first some trouble by heating the armature and pole pieces, if the average current exceeded 50 ampères. This difficulty, however, was successfully overcome. The same plant was tested, under different circumstances, about three weeks

before these tests were made, and the conversion was then 42 per cent., with a delivery of about 42 gallons per minute through 850 feet. The rise of efficiency in the later trials to 44·4 per cent. was probably due to the friction of the bearing surfaces being lessened by wear and by the shortened length of piping, but more so by the introduction of the belt transmission, which protected the motor from the vibration which is inseparable from high-pressure pumping plant.

The experience gained with this small plant was considered so satisfactory by Messrs Locke & Co. that they proceeded in February, 1888, to establish electrical machinery for pumping on a large scale.

This installation was designed to raise about 7,200 gallons per hour from a vertical depth of nearly 900 feet below the surface at one lift. There was a salt-water feeder giving 5,100 gallons per hour, and the margin of power was provided so that the pumps should not require to work more than eighteen hours continuously. In practice, however, they have continuously worked for twenty-two hours out of each twenty-four without any hitch. The pressure on the ram faces being about 400lbs. per square inch, the pumps were specially designed, and as the experimental plant had shown that the load on the rams varied considerably at different periods of the stroke, the motor was specially arranged by Messrs Immisch to meet the electrical conditions produced thereby.

The pumps are differential, with two 6in. and two 4½in. rams, and, when doing full duty, they work at 25 revolutions per minute.

The dynamo and motor are both of Immisch's design, and weigh 4 tons and 3½ tons respectively. Their weight and dimensions are arranged with a view to slow speed, cool running, and steady working, without much sparking, although meeting a variation of load amounting to 30 per cent. during every revolution of the pumps.

The speed of both dynamo and motor is 450 revolutions per minute. Details of the form of pumps, and of the arrangement of gearing for reducing speed, have not been published as yet.

The motor is, however, driven by belt and spur gearing of about 6 to 1, the pumps working at about 17 strokes per minute. The E.M.F. at the dynamo terminals is 600 volts, and at the motor terminals 575 volts. The average current is 66 ampères, but it varies with the load at least 10 ampères on either side of the mean current, and thus introduces increased heating effects, which, however, are successfully provided for in the design.

The actual horse-power represented by the water lifted is, at the rate of 120 gallons per minute lifted 900 feet, nearly 33 H.P. The output of the dynamo being 53 horse-power, the efficiency in terms of actual useful work, compared with this output, is $\frac{33}{53}$ = 62 per cent. approximately. No test of the power transmitted to the dynamo by the belt having been given, the commercial efficiency of the plant, or the ratio of useful effect to the power delivered to the dynamo, cannot be given accurately. The efficiency of the dynamo being, however, assumed to be 85 per cent., which is not a high figure, the commercial efficiency would be $\frac{33}{62 \cdot 5}$ = about 50 per cent. This includes all the losses in transmission; these being loss by conversion in the dynamo, loss in the cable, loss by conversion in the motor, and friction in gearing, pumps, and pipes. About 2·5 horse-power are lost in the cables, and nearly 13 horse-power are absorbed in gearing and pumps and friction of water in pipes. The engineer of the colliery has stated, as the result of twelve months' working, that the useful effect obtained is over 40 per cent., so that it is evident that this estimate of the commercial efficiency is not far wrong.

A test taken by Mr G. Beith* showed the following:—

Indicated power of engine,.....H.P. cylinder, 37·2 horse power.
L.P. „ 39·4 „

76·6 H.P.

Electrical H.P. in generator, $\frac{610 \text{ V.} \times 65 \cdot 5 \text{ amp.}}{746} = 52 \cdot 2$ E.H.P.

H.P. at Pumps—

118 Gallons, 860 Feet high,..... $\frac{1180 \times 860}{33{,}000} = 30 \cdot 7$ H.P.

Giving a useful effect of 40 per cent.

* Proc. S. Wales Inst., Eng., Vol. xvi. p. 151.

The engine is a compound semi-portable Robey, 30 horse-power nominal, indicating from 76 to 80 H.P., and working at a boiler pressure of 140 lbs. per square inch. The cables are capable of transmitting 100 H.P., and were run down the shaft in six hours by three or four men.

The electrical plant, including the engine, dynamo, cables, motor, and gearing, costs £1600; the Robey engine costing £665, and the cables £165 per mile.

This electrical plant replaced a smaller installation driven by compressed air, which did not give 20 per cent. efficiency, and the colliery engineer estimated that to do the same work by means of compressed air machinery would involve a first cost at least 25 per cent. higher, and double the engine power.

Since this large pumping plant was successfully worked, a smaller pumping plant of about 20 horse-power has been started in South Wales. The electrical machines have been made by Immisch, and have some improvements on those at Normanton, by which the sparking at the brushes has been almost entirely prevented. No details have as yet been published.

Scotland, though behind-hand in this matter, has, we are glad to say, commenced to follow so good a lead, and there is actually at work near Linlithgow an electrical installation for pumping water, which has some very interesting features. The motor and pump are situated at Kingscavil Quarry, near Linlithgow, where they raise water to a reservoir at a height of 135 feet, the water being forced through a distance of 600 yards of two-inch pipes. The quantity of water raised has not been stated, but the pumps are double-acting plungers of 2½ inches diameter, designed to work at about 40 revolutions per minute. The dynamo is situated in the engine-room of the Linlithgow Oil Coy., at a distance of fully a mile and a quarter from the quarry, so that the power is transmitted electrically over 4000 yards of cable. This not being an underground case, the cables are naked and are carried by insulators on telegraph poles. The E.M.F. at the dynamo terminals is 250 to 300 volts, and the current 11 to 12 ampères, the output being thus about 3000, Watts, or about 4 H.P., and a margin of 30 to 40 per cent. over present require-

ments has been allowed for future use. This is a small installation, but will serve as a demonstration of what can be accomplished. It works satisfactorily, and requires no attendant at the pump-house at the quarry. The electric machinery is also of Immisch's make, and this case is mentioned because it is probable that electric pumping may be introduced into the shale mines of the Company as the result of this trial.

At Allerton Main Collieries, near Leeds, some small pumps are used, which are applied to deal with small quantities of water at inaccessible points, principally at the working places. They are worked from storage batteries, which are charged at the surface and carried to the pumps in the colliery tubs. Mr Blackburn, the manager of these collieries, informs the author that he has patented that method of working electrically in mines, and that the pumps are working satisfactorily.

(2) WINDING.—At the bottom of the New Stassfurt mine* an inclined shaft was made at a slope of 40 degrees to ascertain the depth of the potash salt bed. The mine is about 1180 ft (360 metres) deep, and the engine at the surface is about 520 ft. (155 metres) from the shaft bank, whilst the winding gear was about 40 metres, or about 130 ft. from the shaft bottom. The total length of electrical cable required was thus about 607 yards. A Siemens (D_0) dynamo giving a current of 22 ampères and 370 volts was already in the engine-house at the surface, having been used for some time for a small electrical railway in the mine. Naked conductors ran to the shaft, and a covered cable laid in a wooden trough continued the connection to the shaft bottom and in-bye to the motor which was in November, 1885, established for winding from the new inclined shaft. This was also a Siemens machine (D_1 type), running at 1000 revolutions per minute. It drove the winding drum by belt to an intermediate shaft, and spur gearing—the intermediate shaft being driven at about 300 revolutions by a belt 6¼ ins. broad, and the spur gearing reducing the revolutions of the drum to 13·3 revolutions. The drum was 4 ft. 1 in. in circumference, its axis being horizontal, and the direction of the winding ropes being reversed by

*Min. Proc. Inst. C.E., Vol. xcv. p. 500.

guide pulleys about 3 ft. 3 in. in diameter, at a distance of about 13 ft. from the drum. The whole of the winding machinery was contained in a gallery 60 ft. long by 12 ft. high. The use of the intermediate shaft and belt were proved to be advantageous in practice, as the load was started and stopped without shock, and regularity of motion was obtained.

The work to be performed consisted of the lifting of a loaded tub weighing 2645 lbs. (nearly 24 cwts.) gross, and the lowering of an empty one weighing 880 lbs., through a vertical height of 328 feet, on an inclined plane about 500 feet long, once in four minutes; or, allowing for hooking on and landing, an actual working time of three minutes, or average working speed of three per second. This required an effective power of about 3120 ft. lbs. per second for lifting, and 154 ft. lbs. for overcoming friction, or in round numbers, 3300 ft. lbs. per second, or 6 H.P. per minute as the useful work of the motor. The useful effect realised being 40 per cent., this required about 15 H.P. at the steam engine. The losses in this case were about 25 per cent. loss by the driving gear of the rope drum, and 5 or 6 per cent. loss in the cables. The useful electrical effect realised was not less than 53 per cent.

Reversal of the motor was effected in the ordinary way by throwing into gear a second set of brushes simultaneously with the throwing off of the first pair, and a resistance was used in order to prevent heating when stopping, starting, or reversing.

This machinery was in constant use without hitch or accident of any kind till the end of March, 1887, when the work was completed for which it was established.

(3) HAULAGE.—At the Short Mountain Colliery of the Lykens Valley Coal Coy. in Philadelphia, a large electrical locomotive for underground haulage was started in the autumn of 1887, and a second was being built in September of last year. This locomotive weighed 15,000 lb. and had a 25 H.P. Schlesinger electro-motor driving by chain gearing; the electric current being supplied by a 50 H.P. Schlesinger dynamo at the surface, and conveyed to the motor by a T rail placed alongside the track on insulated posts about 20 inches above the ground level. From this rail, the con-

ductors with several rolling contacts carries the current to the motor, the track rails being used for the return part of the circuit.

The length of the track is 6300 feet, and the locomotive hauls daily, at a speed of 6 to 8 miles an hour, some 500 tons. The largest load it is capable of taking is said to be 150 tons. The time taken to make an all-round trip is about 14 minutes—or a trip with empty waggons in 8 minutes, and a loaded train brought out in 6 minutes—as against 50 to 60 minutes required to make the round trip with mules. There are several gradients on the line, and a large number of curves, one being of 30 feet and another of 25 feet radius.

At Veteran Tunnel, Aspen, Colorado, two sets of rope haulage drums are stated by Mr F. Brain to be working with 10 H.P. Sprague motors, and a third was being erected at the date of Mr Brain's paper read at the Bath meeting of the British Association last year. These are said to draw six trains at the rate of 500 feet per minute up a 3 per cent. gradient.

Mr Brain also states that an electric locomotive for haulage is working in the salt mines of New Stassfurt, and also at Salzberg Works; and also that at New Stassfurt tail-rope haulage has been applied.

In England, after the exhibition and testing of the electrical haulage plant at Newcastle Exhibition, this application of electricity seems to have begun to make progress. The Newcastle plant was arranged for haulage by a stationary motor, coupled by worm gearing to the driving sheave. A 15 H.-P. Immisch motor was used, and the line was designed for a traction of 12 cwts. The motor was reversed by the employment of two sets of brushes in a rocking frame, and, on starting, some iron resistance coils were put in circuit, which were switched out as the speed increased. With this arrangement, the tubs were under perfect control, and a very sudden stoppage could be effected by reversing the motor with the resistances in circuit. The line was 100 yards long, 2 ft. guage, and laid with 28 lb. rails, the sleepers being at intervals of 3 ft., just as in an underground road. The rope was 1½ in. in circumference, and was carried round 5 ft. sheaves at each end of the line. The sheave at the lower end had keyed

to its shaft a worm wheel, which geared into a worm coupled to the motor shaft by a flexible coupling. The gearing ran in an oil bath. The worm was single-threaded, and the wheel had 75 teeth; thus the motor made 75 revolutions for one of the driving sheave; and 75 revolutions of the motor corresponded to a movement of the rope of about 15·75 ft.

The worm was cut from cast steel, the wheel was cast in iron. This gearing, however, was by no means satisfactory; the friction was considerable, and caused serious heating of the worm and wheel. The worm pitted a little, though it stood the running fairly well, but the wheel wore away rapidly. The efficiency of such gearing is not more than about 40 per cent., as will be seen from the figures given. The tubs were 7 in number, and were filled with scrap iron and loose ballast, making a total rolling load of 5 tons 6 cwt. 1 qr. 7 lb. The motor was designed to run at 1000 revolutions per minute, and to give out 15 brake H.-P., the electrical quantities being 300 volts and 15 ampères. The designing of the various parts of the apparatus, however, resulted in the load being too light for the motor, but too heavy for the gearing. Since the motor was too powerful for the work, the speed and current varied, as shown in the table of observations made during the test. The tractive force required to move the loaded tubs and the rope varied between 312 lbs. and 704 lbs. This heavy traction is to be explained by the surface of the rails being in a very bad condition. The tension on the rope was also considerable, but it was necessary to prevent surging, since the rope only made a little more than half a turn round the driving sheave. The road had a variable gradient, but rose roughly 1 in 75 on an average, though at places, judging by the tractive force rising to 700 lb., the gradient must have been a good deal heavier. The following tabulated figures will show in a convenient manner the results attained. The test was made by Mr M. Walton Brown, representing the Haulage Committee, assisted by Professor Garnet and Mr W. B. Sisling; Messrs Immisch & Co. being represented by Mr Albion T. Snell. The experiments showed that, with a little more attention to details, electrical haulage might be made a decided success underground, with an efficiency twice as great as that obtained with hauling engines driven by compressed air.

TABULATED RESULTS OF TEST.

Work Done.	Gradient.	Volts.	Amp.	Speed of Motor.	E. H. P. put in Motor.	Time taken for Tubs to travel 100 ft. in centre of track.	Speed of Tubs during this time in miles per hour.	Traction as measured by Dynamometer.
7 Loaded Tubs	Up	280	31·5	1,500	11·8	21 seconds	3·25 miles	*Average* 442 lbs. at first portion of *up* grade. *Average* 504 lbs. in centre of *up* grade. *Average* 704 lbs. at the end of *up* grade.
,,	Up	280	31·5	1,300 ?	11·8			
,,	Up	301	28 / 32	1,520	11·4 / 12·9			
,,	Up	280	28	1,360	10·5			
,,	Up	280	27	1,380	10·2			
,,	Up	280	30	not taken	11·3	23 seconds	3 miles	
,,	Up readings taken at different parts of the line	287	35	1,100	13·5	Start	3·25 miles	
,,		287	33	1,200	12·7	21 seconds		
,,		294	30	1,300	11·8			
,,		294	26	1,500	10·3	Finish		
,,	Down	294	23	1,760	9·1	17 seconds	4 miles	Average throughout the *downward* grade. 312 lbs.
,,	Down	291	25	1,740	9·8			
,,	Down	308	24	not taken	9·9			
,,	Down readings taken at different parts of the line	280	28	1,150	10·6	Start	4 miles	
,,		308	21·5	not taken	8·9	17 seconds		
,,		280	23	1,780	8·65	Finish		
,,	Down readings taken at different parts of the line	280	27	1,300	10·2	Start	4 miles	
,,		287	26	1,400	10	17 seconds		
,,		301	23	1,600	9·4			
,,		308	23	1,750	9·6	Finish		
Rope running without tubs	Down	217	15·75	1,720	4·5			
,,	Up	213·5	15	1,720	4·3			
,,	Up	213·5	17 ?	1,620	5·25			
,,	Up	150	14·5	1,300	2·93			
,,	Up	145	13·5	1,250	2·63			
,,	Up	137	13·5	1,140	2·48			
Motor running with worm out		90 to 93	6	1,350	·725 to ·75			

Average work done on the rope on the up grade was

$$\text{1st part} \quad \frac{442 \times 285}{33{,}000} = 3{\cdot}3 \text{ H.-P.}$$

$$\text{2nd part} \quad \frac{504 \times 285}{33{,}000} = 4{\cdot}3 \text{ H.-P.}$$

$$\text{3rd part} \quad \frac{704 \times 285}{33{,}000} = 5{\cdot}75 \text{ H.-P.}$$

Average work done on the rope on the down grade was

$$\frac{312 \times 352}{33{,}000} = 3.34 \text{ H.-P.}$$

The weak point about the gearing undoubtedly lay in the very small pitch of the worm wheel and screw. The screw had only a single thread, and as the worm wheel was 30 ins. in diameter, with 75 teeth upon it, this corresponded to a pitch of only 1¼ in. The driving sheave was 60 ins. in diameter; and, therefore, when the traction on the rope, as measured by the dynamometer, was 504 lbs., the pressure between the screw thread and the worm wheel must have exceeded 1008 lbs. on account of the obliquity of the thread. Taking the effective diameter of the screw as 4 in., and making 1370 revolutions per minute, the relative velocity of the rubbing surfaces was 1435 feet per minute. If we take the electrical horse-power taken up by the motor as 12, when the tubs were running up hill and the traction amounted to 504 lbs., and if we suppose the efficiency of the motor to be 90 per cent., which is probably rather above the mark, as it was running with less than its full load and at 37 per cent. above its normal speed, we have for the break H.-P. 10·8. The actual H.-P. developed on the rope amounted to 4·36, leaving 6·44 H.-P. absorbed in the friction of the gearing. This would correspond to a co-efficient of friction between the screw and worm wheel of nearly $\frac{6{\cdot}44 \times 33{,}300}{1{,}008 \times 1{,}435}$ or ·146. Taking the run down hill in the same way, the co-efficient of friction appears to be ·151, but as the speed of the motor was much greater, and the whole power developed less, there must have been a greater percentage absorbed in the motor, so that the results are sufficiently consistent. As the cast iron worm wheel wore very rapidly, and the oil became very gritty, it

is probable that the co-efficient of friction was not less than ·14. Had a worm been employed of 6 in. pitch, as recommended by Reckenzaun, the loss by friction would have been reduced to about one-fourth of the actual loss experienced, and the efficiency of the system would then have been 66 per cent. This could have been effected by using a 3 ft. sheave and a 4 ft. worm wheel, doubling the speed of the tubs, and running about 10 tubs instead of 7. At the time the measurements were taken, the gearing had been running some time, and the oil in the bath was thoroughly impregnated with finely divided iron from the cast iron worm wheel. In future experiments, it would be well to employ a steel worm wheel, and great care should be taken to ensure that the casting is perfectly free from sand before it is placed in the oil bath.

It is satisfactory to know that two installations of electrical haulage plant by fixed motors of good size are either recently completed or about to be started in England and Wales.

One is a 50 H.P. plant, at Messrs Locke & Co.'s (who have already been referred to in connection with pumping by electricity), and the other is a 20 H.P. plant at Messrs Partridge, Jones, & Co., at Pontypool. The details of these are promised in a paper shortly to be read by Mr Snell, of Messrs Immisch & Co.'s, who are the makers of the electrical machines, and this information, with some account of their working, will be received with much interest.

One of the most interesting forms of apparatus for the work of hauling in mines is the self-contained electrical locomotive, or the electrical locomotive worked by means of storage batteries. In this arrangement all danger and loss from the necessarily naked conductors used at Zaukerode, Lykens Valley, and elsewhere, are avoided; the locomotive can travel equally well over every portion of the road without requiring the outlay involved in providing a conductor for it; and the power consumed is proportional to the work actually done. There are, of course, certain limiting conditions which determine the suitability of electrical traction for the work of haulage in mines, and these are chiefly the gradients of the road, the necessity for re-charging the accumula-

tors frequently, and the danger from sparking. The first two are common to the use of all kinds of locomotives, and the third applies equally to both kinds of electrical locomotives, and to all electrical machinery where there is danger from gas, and where it cannot practically be placed in the intake current.

It appears that the first self-contained electrical locomotive for mining was designed by Mr Reckenzaun for the Trafalgar Colliery, and that a description and illustration of it were given in the journal "Industries" on 25th June, 1886. An illustration with a record of tests and results of its work was also given in an American work on "The Electric Motor and its Applications" (New York, 1887).

This locomotive was built for a gauge of 2ft. 7ins., but with a very short wheel base. It was worked by a Reckenzaun motor of 8 H.P. gearing, with the axles of the wheels by worm and wheel gear, as in Reckenzaun's tramway car. E.P.S. storage cells were of course used, and were all carried in the body of the locomotive. A compound switch was placed at each end of the locomotive by which the motor could be started, stopped, or reversed. The one pair of brushes being fixed in position, reversing was accomplished by reversing the direction of the current. The following table gives the results of tests when running the motor with a balanced Prony brake to measure the mechanical power. This gives a more favourable condition than can be found in the actual work of a mine roadway.

No. of Test.	Revolutions per Minute.	Electrical Measurements.		Prony Brake.		Electrical Energy. — Horse-power, $\frac{E \times C}{746}$	Mechanical work. — Horse-power, Measured.	Percentage of Return.
		Volts.	Current in Ampères.	Length of Lever in Feet.	Weight on Scale in Lbs.			
1	1,020	105·00	35·5	2·625	7	4·98	3·568	71·65
2	1,013	107·00	40·0	,,	8	5·73	4·027	70·59
3	982	104·75	39·5	,,	8	5·55	3·930	70·80
4	860	95·50	43·25	,,	9	5·53	3·870	70·00
5	970	106·50	43·0	,,	9	6·14	4·385	71·40
6	900	101·78	46·75	,,	10	6·38	4·500	70·50
7	1,022	113·60	47·0	,,	10	7·15	4·110	71·40
8	1,048	114·88	47·75	,,	10	7·35	5·240	71·30
9	1,047	121·88	53·0	,,	12	8·66	6·282	72·50
10	1,070	122·64	54·0	,,	12	8·87	6·420	72·30
11	950	113·87	62·0	,,	14	9·46	6·650	70·30
12	1,040	127·70	72·0	,,	17	12·32	8·850	71·80

During last year a very serviceable form of this kind of locomotive was designed by Mr G. Blake Walker, of the Wharncliffe Silkstone Colliery, in conjunction with Messrs Immisch & Co., who undertook the electrical work with its difficult problems. Mr A. T. Snell has already given* an account of the means adopted by his firm to meet the electrical requirements, and Mr G. B. Walker has given† a short account of the locomotive and the results obtained during three months' trial of it on a surface line consisting chiefly of an incline of different gradients. There is a short piece level at the top, about 200 yards. of 1 in 70; about 150 yards of 1 in 40; about 250 yards of 1 in 25; and about 200 yards of 1 in 40.

The locomotive was made to work in a drift 4 ft. high by 4 ft. 6 ins. wide, the gauge of the rails being 1 ft. 9 ins. The total weight of the locomotive in running order is about 2½ tons, about 2000 lbs. of this being due to the storage cells. The locomotive consists of a well-braced wrought iron frame, carrying a strong oak platform, running on four 16 inch wheels, with guard plates, springs, and axle-boxes outside the wheels. The four wheels are coupled by connecting rods and cranks outside the axle-boxes, in order to utilize fully the weight for adhesion. The accumulators are carried principally on the oak platform in boxes, but in order to secure a maximum degree of steadiness, four sets of accumulators are suspended at each end of the engine below and from the platform, occupying the space between the wheels and the ends of the frame, and behind the buffer bars. Mr Walker has stated that the effect of carrying so much weight at a low point has been to prevent pitching almost entirely, so that the liquid in the storage cells is not much agitated.

The storage battery consists of forty-four modified Tatham cells, each box being 10 ins. by 6½ ins. by 11 ins. high. The boxes are lead lined, and arranged in sections of three in wooden trays. Each box contains nineteen plates, 7 ins. by 4¼ ins. by $\frac{7}{32}$ ins. thick, and has a capacity of 150 ampère-hours, the weight being 53 lbs. The rate of discharge varies between 25 and 50 ampères, and at starting rises occasionally to 65 ampères. Taking 40 ampères as

* Trans. Midland Inst., Eng., vol. xi., p. 333. † Ibid., p. 329.

the average rate, the weight of these cells per horse power works out to nearly 500 lbs.; and per horse power hour storage capacity to 134 lbs.

The motor, which is placed underneath the platform and between the wheels, is of the ordinary Immisch type. The armature is 10 ins. diameter, and wound with No. 12 S.W.G. wire. There are 480 wires counted around the periphery, and the commutator has 48 sections. The resistance of the armature is ·23 ohm. The field is of the double horse-shoe type, and wound with No. 9 S.W.G. wire in two parallels, there being 560 effective turns. The resistance is ·14 ohm, or total resistance of the motor ·37 ohm. The normal current is 45 ampères, and the speed 1000 revolutions per minute, with a terminal pressure of 100 volts. The weight of the motor is 4 cwt., and it gives 4 h.-p at 800 revolutions per minute. On the armature spindle is a small phosphor bronze pinion; this gears into four steel pinions, placed in the same plane, and 90° distant from each other. These pinions are bushed with gun metal, and run on steel pins carried on a cast iron disc. The disc revolves on a journal turned outside of the end of the motor bearing. Outside of, but in the same plane as these pinions, is fixed an annular casting of gun metal, with teeth cut on the inside. The steel pinions gear into the ring, which forms a fulcrum on which they revolve when the motor spindle turns. The power is transmitted from the cast iron disc by a sprocket pinion keyed to it on the inside next the motor, and a steel chain connects this sprocket pinion to a suitable wheel mounted on one of the axles, whilst the other axle is connected with this by the coupling rods already mentioned.

One of the problems of the construction of this engine was the devising of this speed reducing gear, which had to be adopted in the present case on account of the confined space, and the great difference in speed between the motor spindle and the driving axle. The direction of motion is reversed by a switch, which reverses the magnetisation of the field, and the speed is regulated by iron resistance coils. A brake is also provided.

The electricity for charging the cells was obtained from an Immisch 7 H.P. dynamo, driven by a small Willans steam engine, having three cylinders 5 in. diameter, and making about 350 revolu-

tions per minute. Mr Walker states that the dynamo gave out in practice $\frac{120 \text{ volts by } 35 \text{ amp.}}{746} = 5{\cdot}63$ E.H.P. The charge put into the accumulators was 200 ampère-hours or 5·7 hours at 35 ampères, and that the work done by the steam engine was 5·7 + 6·62 = 37·73 H.P.

On the gradient of 1 in 70 the locomotive would just move a train of twenty loaded corves, weighing together 11 tons, and with 15 corves representing 8½ tons, a speed of three miles an hour was obtained, the current being 45 ampères at 100 volts pressure. On the gradient of 1 in 40 the maximum load was eight corves, and on 1 in 25 it was six corves, the speed being a little over two miles an hour. On the level the locomotive could draw thirty corves, the current being 45 ampères.

These trials having shown that the supply of current from the accumulators was inadequate, the speed, and therefore power, of the engine being too low, Messrs Immisch undertook some re-arrangement by which the storage capacity, as compared with the weight, would be increased. Thereafter the same engine was to work at practical hauling in Aldwarke Main Colliery, and results of this work may be given shortly.

In addition to these developments, a trial has been made in applying electricity to the work of coal-cutting both in America and in England. The American machine is said to consist of a number of augers driven by a motor. The English machine has been patented by Messrs Bower & Blackburn, of the Allerton Main Collieries at Woodlesford, assisted by Mr Mori, an electrical engineer.

The framework or bed-plate of the machine is supported on wheels. Within the framework is mounted the electric motor, which may be of any suitable construction. A rotary motion is transmitted to the shaft carrying the cutter bar through gearing. The lower part of the framework forms a circular turntable, and is fitted so as to be capable of a rotary movement on the bed-plate, this rotary movement being effected by means of a worm, and worm-wheel segment, attached to the upper part of the framework. By this means the cutter bar can be moved along by the attendant as the coal is being cut, and the proper feed

given thereto. Although by preference the motor is carried on or attached to the coal-cutting machine, it may be placed at any convenient distance therefrom, and motion transmitted from it to the machine by gearing.

Mr Blackburn informs the author that they have also a special machine for running at a high speed and working close to the solid coal, so as not to have more than 5 inches of undercut coal overhanging at any time. This he has found necessary in order to prevent jamming of the cutter by pressure of the coal downwards. Mr Blackburn prefers to connect his cutter bar direct to the motor shaft, and run it at a high speed; but he uses a chain or other gearing where he has to bore below the level of the motor shaft. He says that in fair circumstances 130 yards per day, or 20 yards per hour, may be done, but much depends on the thickness of the seam. He uses a machine of 6 H.-P. for light boring, and one of 10 H.-P. for heavier work, and the coal is got in good condition with about 5 per cent. of small.

In America, some ideal installations are at work. At Silver City, Idaho, a Sprague motor is used at a mine to drive a 50-stamp mill four miles from the waterfall which, by means of a turbine, drives a dynamo giving out 75 horse-power. The manager of this mine has stated that he saves in the haulage of his ore alone 90 dollars a day.

The following is given by Mr Frank Brain:—At Big Bend Tunnel Camp, Butte County, California, a tunnel 16ft. by 12ft. and 2⅓ miles long, is cut from the Feather river through the mountain. A permanent dam built across the river just below the head of the tunnel diverts the whole stream into the tunnel, and a canal, two miles long, extending from the other end of the tunnel, enables a fall of 300 feet to be obtained. Here powerful Pelton water-wheels are fixed driving Edison dynamos. The working E. M. F. produced is 1000 volts; the conductors are double metallic, and extend a distance of eighteen miles, delivering electricity at fourteen different points in the circuit where power is required for winding, pumping, &c. Some ten to twenty Sprague motors, varying from 5 to 50 H.-P., are worked by branch conductors from these various stations, the potential

at the motors varying from 500 to 700 volts. The saving in fuel alone, where such a transmission and distribution of power derived from water is possible, may be very great in some mining districts; and the ease with which any amount of power can be conveyed over hill and dale, and into the intricacies of mines, are factors of no mean importance.

It is apparent from this rapid survey that the prospects of electrical development in this very important field of engineering are most encouraging. The questions of efficiency and cost seem to be satisfactorily settled, and perhaps the only matter which prevents full confidence in electrical methods, is that of the possible ignition of gas by the sparking of machines. This is not an insuperable difficulty, and the surest way to eliminate all uncertainty, and to reach the greatest perfection in the development of this marvellous form of power, is by a more ready and general use of appliances which even now possess so much to recommend them. This is how so much progress has been made in America; and here, as there, it rests with the users of power to cause this advance to be made.

It has been desired that a note should be added, giving some explanation of the technical terms used in describing electrical work.

The source of almost all the power which is available for industrial purposes is the heat which is derived from the combustion of fuel, and in speaking of heat we use terms to denote its intensity and its quantity. The *intensity* is denoted by the temperature (according to a scale of thermometer degrees), and the *quantity* by the number of heat-units or Calories available (these are usually measured by the number of lbs. or grammes of water raised through a certain range of temperature).

Water, steam and air are the principal fluids used as carriers of power, and in speaking of their work we use terms to denote pressure and volume, for obvious reasons.

Pressure is expressed in lbs. or tons per square inch (or in the case of water, the vertical height of a "head" or column is sometimes made use of, for this produces a given pressure), and these might have been called "Bourdons" or something else. *Volume*

is expressed by cubic inches at that pressure, and these, it is manifest, might have been named "Euclids" or something else. The pressure corresponds to the temperature in speaking of heat, and is therefore connected with the intensity or quality of the force used, and with the idea of the *rate* at which work can be done. Volume corresponds to the quantity of heat, or the *amount* of work which can be done. Now, inasmuch as electricity behaves in some respects like a fluid, we may compare the terms applied to it with those which are used in the case of water, steam, or air, and thus, instead of pressure in lbs. per square inch, we have electric pressure or electro-motive force in "Volts" (so called after Volta), and, instead of so many cubic inches of quantity or volume, we have so many "Ampères" of quantity or current.

Such comparison is, however, not without drawbacks, for it tends to popularize a material, and probably erroneous, conception of the nature of electricity. It seems to be more simple and more just to compare electricity with heat, as both are forms of force or energy. Thus the intensity of the force is in one case expressed by the number of Fahrenheit or centigrade degrees—which might as well be called "Fahrenheits" or "centigrades"—and in the other case by the number of Volts, a Volt being a definite measure of electrical force which produces a certain effect against a definite resistance. The quantity or amount is, in the case of heat, "Calories" or heat units; and, in the case of electricity, "Ampères" or current units. This analogy will be found to hold good in many interesting and minute details.

All work is done against resistance in some form, which in power transmission is denominated "friction," and always tends to produce heat.

In using water, steam, or air the friction is represented by so much pressure or power absorbed, and can be expressed in a given case by means of "co-efficients of friction," which have been determined by experiment. There is, however, no unit-measure of friction used, although it would be manifestly easy to take a definite length of pipe, say one thousand yards, and having found the proportion of power or pressure which was absorbed by friction in it (using different sizes of pipes for different

pressures of fluid) to fix upon a unit-measure of friction considered as resistance to the flow of fluids, and to give it a definite name.

Resistance to direct heat transmission would require to be treated in a different way, but the analogy would be more complete. In electrical matters a unit-measure of resistance has been ascertained by the employment of a definite length of pure copper wire, and this unit has been called an "Ohm," after a celebrated electrician of that name.

An E.M.F. (pressure or difference of potential) of 1 Volt will produce a quantity effect (or "current") of 1 Ampère against 1 Ohm of resistance. These terms can be correlated with the more familiar "foot lbs." and "horse-power" by remembering that 1 Volt × 1 Ampère = 1 Watt (or 1 Volt-Ampère), and 746 Watts = 1 electrical H.P. A "Watt" is therefore equal to 44·236 foot lbs.

Ohm discovered a law which is thus expressed :—$C = \frac{E}{R}$, and from this we may find either element, thus: $E = C \times R$, and $R = \frac{E}{C}$.

The PRESIDENT said they could not discuss the paper at that meeting, but he was sure they would all read Mr Rowan's paper, when it appeared in print, with very great interest.

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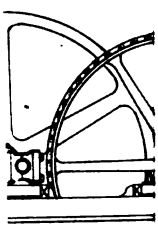

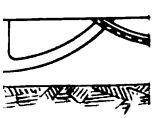

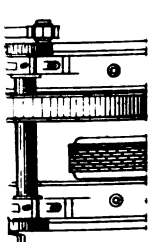

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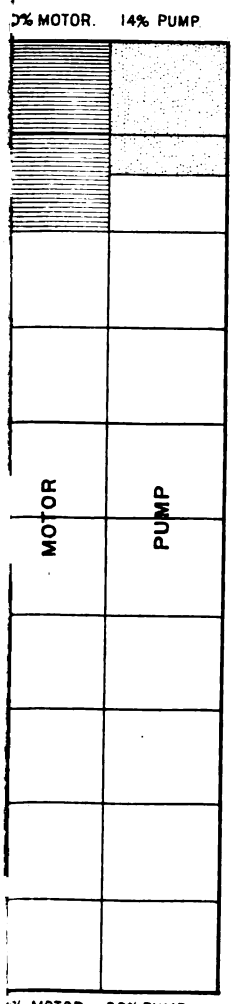


THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,

30th May, 1889.

JOHN M. RONALDSON, Esq., President, in the Chair.

The Minutes of the Twelfth Annual Meeting were read by the Secretary and confirmed.

The following were elected by ballot as Ordinary Members :—

JAMES ROBERTS, Holmes Oil Works, Uphall.
JOHN W. FOSTER, Silksworth Colliery, Sunderland.

The following Discussion then took place :—

DISCUSSION OF MR F. J. ROWAN'S PAPER ON "RECENT DEVELOPMENT IN THE APPLICATION OF ELECTRICITY TO MINING."

The SECRETARY read the following communication from

Mr T. LINDSAY GALLOWAY—Mr Rowan's paper gives particulars of a number of the more recent applications of electricity to mining, chiefly as a means of conveying power to a distance. Descriptions of some of the installations have already been published in the transactions of other Societies; but it will no doubt be useful to the members of this Institute to have the various results brought together for the purpose of comparison. It is to be regretted that in several instances mentioned in the paper the plant was not all uniformly good. At Trafalgar Colliery, for instance, the steam engine from which the power was derived appears to have been rather defective. At St. John's Colliery the slide valve of the steam engine shifted during the experiment. At the Newcastle Exhibition a mere mechanical detail seems to have somewhat marred the success of the apparatus. Any one who has conducted experiments similar to these with any new apparatus must have felt how difficult it is sometimes to get rid of purely extraneous or accidental circumstances which have nothing to do with the merits of the apparatus, but which tend nevertheless to throw discredit on its performances in the eyes of practical men. One reason for such occurrences is that people, as a rule, do not put up expensive plant merely for experiment; and if they happen to have some old machinery not altogether unsuitable which can be turned to account, they are tempted to combine it with newer and more perfect machinery, whereby the latter is often made to suffer.

The advantages of electricity in some of its applications to mining are already well established. Its suitability for signalling, for blasting, and for lighting in certain situations about mines has been proved in many instances. The writer may be permitted to allude to a recent application which has come within his own experience. The electric light in this instance* has been applied

* The Cardiff Steam Coal Collieries Company, Limited. W. Galloway, engineer.

with very good results to illuminate a sinking shaft. The light is supplied by three incandescent lamps of sixteen candle power suspended at a distance of four or five yards above the bottom of the shaft. The effect is excellent, and fifteen or sixteen sinkers are able to work in the shaft almost as conveniently as they could in daylight. The brick lining of the shaft is also built simultaneously by electric light, for which purpose two lamps are found sufficient. Two or more lamps of small power are preferable to a single large lamp, because the light is more diffused and does not cast inconvenient or bewildering shadows. Incandescent lamps have been adopted in preference to arc lamps on account of their greater steadiness and the mild quality of the light obtained from them. At this sinking the shots are all fired by electricity. A large number of holes are prepared—eight or ten in the case of sump shots, and fifteen or twenty in the case of side shots—and all are fired simultaneously, so that there is very little time lost in blasting. Any one who has had experience of this method, and has had the opportunity of comparing it with the older method of firing by time fuses, can scarcely fail to be convinced of the greater security from accident, the saving of time, and the advantages of combined effect which are secured by the adoption of electric blasting for sinking purposes.

Electricity, as a means of conveying power to a distance, has one or two old and formidable rivals. Perhaps it will only be after longer experience that we shall be able to judge fairly between compressed air, electricity, and water, as means of transmitting power from one situation to another. It is well to bear in mind that every method of conveying power involves some loss; but the percentage of loss is not any fixed quantity—for example, so much in the case of compressed air, so much in the case of hydraulic transmission, and so much in the case of electricity. Within certain limits, we can make the percentage of loss either greater or less, according to the rate at which we drive the apparatus. If the apparatus is worked to its utmost capacity, we shall find that a large proportion of the power is wasted; but if it is worked considerably under its full capacity, we shall obtain better economical results—a less percentage of loss, and a larger percentage of useful effect. This remark applies

to every method of transmitting power to a distance. In the case of electricity, it has been stated by the late Sir W. Siemens * that, by means of two dynamos at a moderate distance apart, and connected by a cable, nearly 80 per cent. of the power imparted to one dynamo can be again recovered from the other as mechanical effect, leaving out of consideration the unavoidable but small losses arising from friction. But Sir W. Siemens at the same moment pointed out that, under these conditions, the total amount of force transmitted would be comparatively small; in other words, the dynamos would not be running at anything like their full power. If we wish to develop a greater amount of power, we must make up our minds to be contented with a much lower percentage of useful effect. It would not be possible to discuss this matter fully without going into technical details which might be out of place in the present circumstances; but any ordinary steam engine presents a familiar illustration of a precisely similar law. If a steam engine is to be worked on the most economical principles, it will be fitted with expansion valves, the steam will only be admitted to the cylinders for part of the stroke, and it will then be cut off, and the remainder of the stroke will be completed by using up all the expansive force of the steam already contained in the cylinder. This is the most economical method as regards consumption of coal. But we know very well that, with the same pressure of steam, a smaller engine could be got to do the same amount of work by allowing the steam to be admitted at full pressure during the greater portion of the stroke. This engine would be more wasteful than the former, but its first cost would be very much less. So it is with electric and other appliances for transmitting power. We have to choose between larger and more costly plant, with greater economy, and smaller and cheaper plant, with greater waste of power. Thus, in comparing electrical transmission with the other methods, the size and cost of the installation should be taken into account in conjunction with the total amount of power transmitted and the percentage of useful effect. Viewed in this aspect, the application of electricity to the conveyance of power has not

* "Electrical Transmission and Storage of Power." Institution of Civil Engineers, 1884.

yet shown any marked superiority over other systems; but, judging from the instances quoted by Mr Rowan in the paper, and from other instances published elsewhere, it would appear that the results are sufficiently encouraging to warrant further attempts in the same direction, and, in any case, these experiments are exceedingly interesting both from a scientific and a practical point of view. One circumstance, no doubt, operates in favour of compressed air as a means of transmitting power in the interior of mines, notwithstanding the very considerable losses which are entailed by its use, viz., that the exhausted air forms a sort of "by-product." Coming, as it does, fresh from the pipes, and cooled to a low temperature by expansion, this air, instead of being an impediment, forms a useful addition to the ventilating current. This is probably one of the reasons why compressed air has been most extensively used in collieries, while hydraulic transmission has been more largely devoted for cranes, dock-gates, lifts, guns, and so forth. It may be doubted whether the electric locomotive has a great future before it in connection with collieries. No doubt it is some benefit to have a locomotive which discharges no smoke or steam, but these difficulties had been previously overcome by a compressed air locomotive; and we may well believe that, if such locomotives had been found well adapted for mining, their use would have extended more rapidly than it appears to have done. The impression which the writer formed, from witnessing the performance of compressed air locomotives when they were introduced some years ago at a Durham colliery, was that, even on a level road, they were not economical, and that they were quite unsuited for the steep gradients which frequently prevail in mines. Underground haulage is a different problem from surface haulage. The conditions which favour locomotive traction on the surface are the necessity of conveying the power over very long distances and upon comparatively level roads. In mines, the distances are short compared with the length of railways on the surface, and the gradients are often so steep that a smooth-wheeled locomotive would be of no use whatever. Undoubtedly there are some situations in mines where an economical locomotive might be applied, and it remains to be seen whether, in such cases, electricity may find for itself

another sphere of usefulness. We can only judge of the merits of such appliances as have been already tried. The history of electricity has been full of sudden surprises, and further developments in its application to mining, in one direction or another, are sure to take place. The whole subject opened up by the paper is full of interest, and the members of this Institute have reason to feel indebted to Mr Rowan for keeping them in touch with some of the most recent electrical appliances.

The SECRETARY added that since Mr Rowan's paper was read he had noticed in the most recent Transactions of the American Institute of Mining Engineers reference to two installations not mentioned in the paper. The first was at Aspen, Colorado. A Brush electric plant, driven by water power in the neighbourhood, is used to pump and hoist underground in the mine and to haul on the main entry. An installation is being put in by the Brush Coy. in the Comstock Mines, Nevada, to be used to drive the new Nevada mill, hoisting engines, &c. "It consists of six Pelton impact water-wheels, 40 inches diameter, each connected directly on to the shaft of a dynamo of 135 horse-power, and these drive six electric motors of 90 horse-power each. The dynamos and water-wheels are placed in a chamber excavated in the mine at the level of the Sutro tunnel. The water is brought down the shaft from the surface and goes through a half-inch nozzle on to the water-wheel under the enormous head of 1630 feet. The power is brought back to the surface over a copper strand about three-eighths inch diameter. The dynamos are of the constant current type, wound for 40 ampères. They are said to be absolutely automatic in the government of their current strength, no current regulator of any sort being required. The variation of current between full load and no load is less than two per cent. The efficiency of both machines, the dynamo and electric motor is considerably over 90 per cent."

Mr ROWAN said Mr Frank Brain, of the Trafalgar Colliery, promised to send him a short account of his method of simultaneously firing a number of shots by electricity, but he had a note from him saying that, unfortunately, he was ordered away for his health, and was not able to send it. He, however, sent him some papers referring to an electrical fuse which he had worked

in the South with very good results, and he (Mr Rowan) now laid them on the table in case they might be interesting to some of the members. He did not think he need take up time referring to Mr Galloway's remarks, because they were pretty full, and there was not much controversial matter in in them. There was one remark he did not quite follow, in which, after showing that small installations of machinery of any kind must necessarily be less economical than larger ones, he rather astonished him by saying that, under these circumstances, electricity had shown badly, whereas, he thought, it was just exactly the opposite. The first installations of electrical plant which had been tried had been small, and in some respects imperfect, and the fact that they had shown such good results, under those circumstances was, he thought, very much in their favour in exactly the opposite ratio to that mentioned by Mr Galloway. There was no doubt if they worked a small plant to its breaking down point, or within a short distance of it, it would not show such good results as if there had been a margin of power. That applied to all machinery, and electric machinery was not exempt from the laws that affected the case of others.

Mr R. T. MOORE said this was a very instructive paper, and he was sure they had all read it with very great interest. It showed them what had been done lately in applying electricity to the transmission of power, and there was no doubt this application was one of the coming things in mining. The examples Mr Rowan gave them showed that it was getting beyond the experimental stage, and was being applied practically to engines of considerable magnitude. He had had an opportunity of seeing the small pump mentioned as being at work in the Linlithgow Oil Works, and he was much pleased with it. It was rather over a mile between the dynamo at the Oil Works and the pump in the Old Kingscavil Quarries. The pump was started by starting the engine in the paraffin house; there was no one in attendance, and the only attention it got was that of a boy who oiled the dynamo. The manager was very well pleased with the arrangement, and it seemed to be working very well indeed. There was no doubt also that the system would be of use for electric locomotives and haulage. There would, however, be a difficulty

from the sparking of the dynamos, for people would not like to apply them where safety lamps were in use, but there were many cases where they could readily be adopted. He admired very much the system of working locomotives with accumulators. He thought a great deal would be done in that way,—more than in working by a system of having a conductor along the road, and taking up the electricity as it went along, because in that system there seemed to be a great loss from leakage. That brought him to one point regarding which he had been disappointed. He had frequently been informed that there was about 80 per cent. of useful effect got in working with electricity. He had been under a wrong impression, for that was not the useful effect of the steam engine as put into the dynamo transmitted through the wire and brought out in the pump at the other side. That useful effect was only some 40 per cent. That is to say, a pump developing 40 horse-power would require an 100 H.P. steam engine to drive it. This was no doubt much better than compressed air, and quite a decent useful effect, but it was certainly not nearly so good as the results got from hydraulic power. Still, it was a step in the right direction, and as electricity was only in its infancy, probably as it was improved they would get at higher results. There was great convenience attending its use. Where the motor was a long distance from the dynamo, the wires were easily led in. There was little trouble in fixing them, and he should think many positions would be found where it would be usefully applied. They were indebted to Mr Rowan for keeping them posted up in what was being done in this direction, and the paper would be of great use for reference.

Mr Geo. A. Mitchell said Mr Moore had just referred to the question of sparking, and this seemed one of the most important drawbacks to the use of electricity below ground, because it appeared they could not get rid of it altogether. They knew that with dynamos for electric lighting, where the resistance is steady and everything in favour of the working, sparking could not be entirely prevented, and still more so would this be the case below ground, in working coal cutters and pumps where the resistance is unsteady, and where it is impossible to keep the motors as

clean as they should be. There must be sparking, and this was a serious matter where safety lamps were used, because coalmasters were not likely to run the risk of throwing their colliery idle for the sake of a small advantage in economy of electrical over other modes of conveying power. He thought it might be a good thing if Mr Rowan explained what had been done to get over this difficulty. He saw that at p. 39 he said it was not an insuperable difficulty. There might be an arrangement, and it would be interesting if Mr Rowan could let them know what means had been tried. It seemed to him, in looking over this paper, that the great advantage of the use of electricity, where it could be used, was in connection with the conveying of power for long distances. They had on p. 20 an example of a pumping appliance where the power was conveyed for 2200 yards, and the loss in taking the power that distance was very small. They found the resistance of the leads was only 11 per cent. or 1 ohm. (if they worked out the calculation), which was not serious when working with a comparatively small current and a large electro-motive force. There were a great many places, of course, where it was difficult to convey power long distances, and it seemed the use of electricity helped to solve this problem. Especially what Mr Rowan referred to on p. 27 would be useful. He spoke there of pumps worked at not easily accessible points by means of storage batteries. Now, there were a great many cases where there was a quantity of water to pump—too small to permit of expensive arrangements, and too large to be drained away by means of hand power,—and it would be a very convenient thing to have a portable arrangement such as described for pumping in such circumstances. He thought this was a good adaptation, and could be easily managed, because such an arrangement could be taken from one part of the mine to another. He very much agreed with what had been said about the haulage below ground. They knew that the system of conducting the electricity,—the T iron arrangement,—worked well on the surface. They had a railway working between Portrush and the Giant's Causeway on this system, and it worked very well, although, as he knew from experience, it did occasionally break down. But the cir-

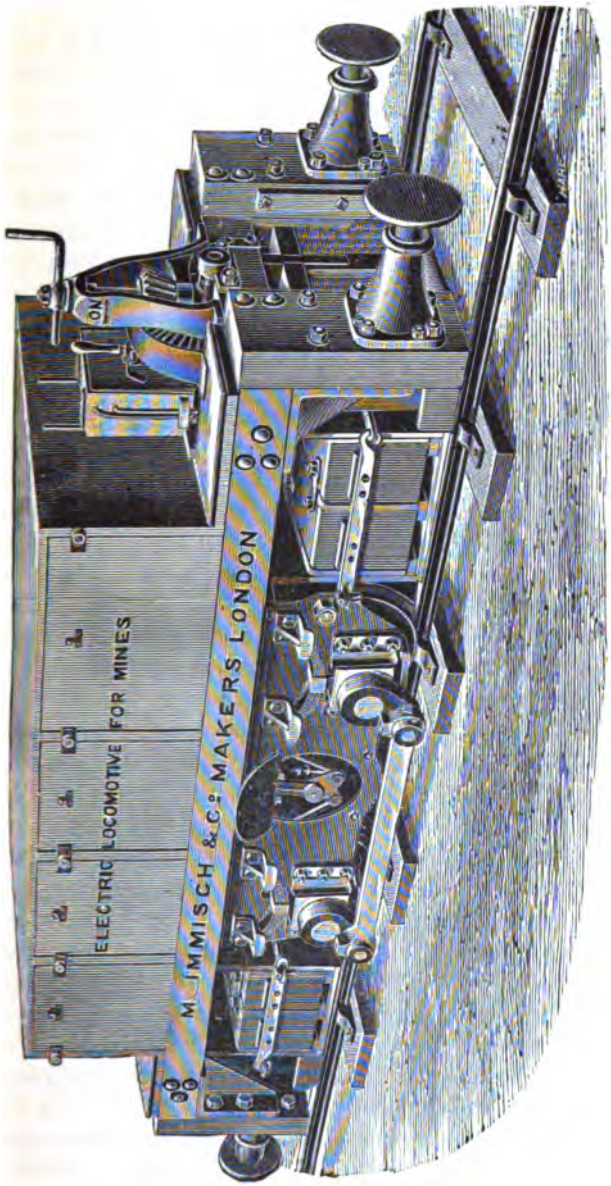
cumstances below ground are quite different. There were so much extra moisture and dirt that there was bound to be a great deal more leakage, and therefore a great deal more power lost. He thought if electricity was to be applied to haulage, it would be in the direction of the use of storage batteries, which were being improved every year, which were rather cumbersome at present, but which they might expect to be useful in the future. He thought the paper had been interesting to all of them, and he thought it was a good thing that they had a member who could place before them in a plain and easily understood way the newest results on this subject. All those could be expected to do who were engaged in mining was to understand in a general way the principles involved. They could not be expected to follow up all the improvements that were being made in a science that was progressing so rapidly.

The PRESIDENT said, as regards the sparking question, he saw the matter discussed very fully in one of the English Institutes—the Midland, he thought. They had a very long discussion. He forgot what was arrived at, but some were of opinion that the difficulty could be got over satisfactorily, while others were sceptical on the point. It was certainly a serious matter as regards fiery mines, and where safety lamps were in use, it would be prohibitory altogether if it could not be overcome. He had no doubt, that, if not already overcome, some means would be devised whereby the sparking would be rendered perfectly safe.

The SECRETARY, referring to the electric locomotive, said he had intended having a drawing of it with Mr Rowan's paper, but he did not get the block in time. He had got it now, and it is here shown.

Mr ROWAN said he would like to say a word about sparking, because that was, as the President said, a most important point. There would always be sceptics, even after it was demonstrated that sparking was harmless. On the occasion to which the President referred, the question was raised in a most serious way, and some experiments had been made, by running dynamos or motors in an explosive atmosphere, to test the question whether a spark which was given off between the commutator and the brushes of the electro-motor would explode a gaseous mixture.

SAN FRANCISCO.



ELECTRIC LOCOMOTIVE,
(Described on Page 35.)

These experiments were carried out to prove whether the spark could fire an explosive mixture, and as far as they had gone they had not succeeded. The reason was simple; the spark was passing directly between the brush and the commutator, and in order to fire gas it must pass through it. Now, the layer of gas that could be got between the brush and commutator was so small, and the resistance in the gaseous atmosphere in the other directions was so great, that it had no tendency to fire an external atmosphere. Besides that, he had hoped to have had a photograph of a motor with the commutator and brushes enclosed in wire casing,—practically inside of a safety lamp, which, he might remark, was a suggestion made at the close of his previous paper on this subject; and in addition to that, Messrs Immisch had constructed a motor to work inside of a case. There must be a current of air passing through such a case to keep the motor cool, but that was taken from the intake, so that there could be no gas in the motor case. He also believed it to be possible to make a motor on a totally different system.

Mr ATKINSON asked what the result would be in the case of the conducting wires breaking.

Mr ROWAN said there would be a flash which would be dangerous if the flash took place in an explosive atmosphere. That could only take place where the continuous conductor in the roadway became broken by some accident. In the case of locomotives worked by accumulators, or those portable pumping plants which Mr Mitchell had referred to, there was no danger from that source. He quite agreed with what had been said that locomotive traction underground was not likely to be so universal as the system of stationary engines, whether electrical or otherwise.

Mr MITCHELL asked if there were not sometimes sparks between different sections of the commutator.

Mr ROWAN said it was not possible to have sparking between the sections, because there was only one or two sections that could possibly be in circuit, and they could only have a spark between these and the brushes.

Mr MITCHELL asked if they could not have a spark between two neighbouring sections.

Mr ROWAN demonstrated on the black board that this was not probable, and afterwards communicated the following :—

J. Meyer* has recently instituted a series of experiments to determine the circumstances under which fire-damp may be ignited by sparks produced either by the steel tools used in working hard rock, or by the friction of pieces of rock against one another. Two to four sharp-edged pieces of steel were pressed, with a pressure of 9 lbs. to 13 lbs. against the periphery of a grindstone of carboniferous sandstone 15·75 inches diameter, and 3·15 inches thick, running at a rate of 250 to 300 revolutions per minute. A continuous stream of sparks of varying intensity was produced, but an explosion was produced only when some of the sparks had an intensity equal to or exceeding the igniting point of the gas. To produce such ignition it was necessary either to force a current of gas against the sparks, or to produce the sparks in the midst of the explosive mixture. Both ordinary illuminating gas and natural gas from a "blower" were used, the latter showing on analysis: Marsh gas, 96·00; carbonic anhydride, 1·10; oxygen, 0·10; other gases, 2·80. No heavy hydrocarbons or free hydrogen could be detected. The illuminating gas was readily ignited after a few seconds, but it was much more difficult to ignite the specimen of fire-damp which was used. When the grindstone was moistened with water, the danger of ignition was considerably lessened.

When pieces of rock were held against the grindstone with a pressure of about 22 lbs., ignition was more readily obtained with both gases, but it was necessary for the rock to be sandstone. A revolving stone of shale with pieces of shale pressed against it produced no sparks.

With reference to the temperatures necessary for the ignition of different gases, the French Commission on fire-damp give the following :—

	Degrees Centrigrade.
Heavy carburetted hydrogen,	550
Hydrogen,	580
Carbonic oxide,	650
Marsh gas,	780

* "Oest. Zeit. für B. u H.," vol. xxxiv. pp. 379-82, and 398-401; "Jour. Iron and Steel Inst.," ii. 1886, p. 881.

Experiments made by the German Commission, however, show that the temperature at which fire-damp ignites is higher than would be indicated by its composition, as they were able to fuse wires of silver and copper in the explosive mixture without igniting it.

The PRESIDENT, summing up the discussion, said they were all glad they had such a member as Mr Rowan to keep them up in this most wonderful power. It was often said that electricity was in its infancy. Well, it was getting a pretty big infant. As to the sparking question, with all deference to Mr Rowan, he did not think it was absolutely settled. He proposed a hearty vote of thanks to Mr Rowan for his paper, which was cordially given.

The following paper on "Gas-fired Boilers" was then read by Mr Rowan :—

ON GAS-FIRED BOILERS.

By Fredk. J. Rowan, C.E.

The use of gaseous fuel for firing steam boilers offers a ready and efficient means of overcoming various imperfections which appear in other methods of firing, and of preventing some of the difficulties which attend these methods.

Variations in the composition and quality of different coals, and even in different parts of the same seam of coal, imperfections of hand-stoking, the nature of the combustion of solid fuel, and the necessity of using a large excess of air which it involves, all tend to make hand-firing with solid fuel a very uneconomical process. The use of mechanical stokers ensures regularity in the charging of the fuel, and in its distribution on the grates, but only meets in a modified degree the other difficulties, while it, of course, does not alter the nature of the combustion taking place, nor affect the varying composition of the fuel in use. It cannot be too clearly understood that, "in order to have complete combustion, it is necessary to have an intimate mixture of, and contact between, the particles of the combustible and those of the oxygen of the air, and also to maintain, during the whole period of combustion, a temperature sufficiently high to allow of chemical action taking place freely. The employment of solid fuel, although in small pieces, prevents the realization of the one, because it is only the surface of the pieces which can be in contact with the air; and the employment of methods of combustion which necessitate the use of excess of air interferes with the other by the inevitable lowering of the temperature." "Again, with imperfect combustion, such as is common to all boiler furnaces using solid fuel, boilers are exposed to the evil of the formation of a deposit of soot (mixed more or less with dust from the ash) on their heating surface (and on that of feed-heaters, where these are used), which considerably diminishes their evaporative efficiency. The use of solid fuel, moreover, causes additional wear to the boilers by the alternate heating and cooling which result from the operation of

charging or stoking, and even from the combustion itself where solid fuel must first be volatilized and then burned in the same chamber." *

The use of gaseous fuel is in direct contrast with these features. By no other means can we obtain that intimate mixture and contact between the particles of the combustible and the supporter of combustion, which are essential to complete combustion. The variations in composition of coal are overcome by the process of producing gas, the volume of gas in relation to the weight of solid fuel being so large that the composition of the gas remains to all intents practically constant, although that of the coal may vary. The formation of smoke and of sooty deposit is prevented, and the alternations of high and low temperature, which are destructive to the boilers, are replaced by an even temperature which the steady stream of flame supplies. The temperature of combustion is not unduly lowered by the admission of excess of air for combustion, and consequently less heat is uselessly carried off by waste gases. It does not appear that the many advantages of this system of firing boilers have been fully realised in any practice with it hitherto carried out, although very good and economical results have been obtained in the case of several examples. On the other hand, coal fires, as applied to boiler-firing, possess one advantage which renders them peculiarly suited to this work, especially where the steaming powers of boilers are forced, and that advantage consists in the large store of radiant heat which they yield when the coal is fully coked and the solid mass on the fire-bars is incandescent throughout. This quality of a coal fire has not been fully imitated in applying gas-firing to boilers, but in instances of forced combustion, which are only partial applications of gas-firing, its advantages are realised, although accompanied by some drawbacks.

Its importance has been demonstrated by an experiment shown by Mr W. Anderson, and before him by Prof. Tyndall, where the radiation from a gas-flame is shown to be greatly increased by the presence of a solid body, which becomes incandescent or glowing in the midst of the flame. Connected with this are the ques-

* Gas Firing for Steam Boilers, by F. J. Rowan: "Trans. Mining Inst. Scot.," vol v. p. 218.

tions of the calorific intensity of the fire, and of the temperature to which the heating-surfaces of the boiler are exposed. These questions are not identical, for determinations of calorific intensity do not include any statement of the amount of radiant heat produced by the combustion of a fuel, or of the evaporative effect of this radiant heat. The calorific intensity of an ordinary coal fire, where twice the theoretical quantity of air required for combustion is admitted, is stated by D. K. Clark* to be about 2614° F., whilst the calorific intensity of ordinary producer gas is variously put at 1800° to 2000° by different authorities. Invariably, however, more air than 24 lbs. per lb. of coal is admitted to coal fires, and the heating effect of these fires is still further reduced by the cooling effects produced by opening the furnace-doors for stoking and cleaning the grates; but yet it appears that, given a restricted boiler heating-surface, but a good chimney draught, more steam may be produced by a forced coal fire under such circumstances (though at the cost of a greatly increased expenditure of fuel) than by gas-firing as ordinarily applied—viz., with cold air for combustion. This shows that the full heating effect of a coal fire is not represented by these temperatures which denote the calorific intensity of the fuel.† On the principle that a steam boiler may be justly regarded as a heat engine, it is evident that the higher the initial temperature is the better, it being understood that this is the temperature actually operating on the boiler-surfaces, provided that, in maintaining this temperature, we do not allow the waste gases to escape too rapidly or to be too hot when escaping, and thus unduly raise the final temperature.

In several instances in which gas-firing has been tested against hand-fed coal fires, under similar conditions as to amount of boiler heating-surface and of chimney draught, the results have shown a higher evaporative efficiency in the gas-fired boiler—that is, a larger quantity of water evaporated from the same surfaces in a given time. A greater weight of water has also been in some cases evaporated with gas per lb. of coal used, although, where cold air has been used for combustion, the difference between the

* "A Manual of Rules, Tables, and Data, &c.," third edition, 1884, p. 408.

† See On the Estimation of the Calorific Value of Solid and Liquid Fuel, by F. J. Rowan: "Jour. Soc. Chem. Indus.," vol. vii. p. 195.

two systems of firing has not been very great in this respect. Where the air for combustion has been heated by waste heat from the exit gases, a much higher temperature of combustion and increased economy of evaporation have been obtained. In those cases in which gas-firing with cold air has shown economical results, it will be found that the steaming power of the boiler has not been forced, either from insufficiency of chimney draught or from its not being necessary to obtain more steam than was being supplied. The question, however, arises, how it happens that, if the temperature of a solid coal fire is higher than that of the flame obtained from producer gas and cold air, the gas flame should be able to evaporate more water from the same surfaces in the same time. This apparently anomalous result will be found to be due to the existence in these cases of a proper relation or ratio between the extent of heating-surface, the rate of travel of the flame and hot gases over the surface (or what is the same thing, the duration of contact between them and the surface), and the initial temperature or the temperature of the fire. The proof that this proper ratio exists will be found in the final temperature or the temperature of the escaping waste gases, which will show the amount of cooling that has taken place. It is evident that, with an initial temperature of 2000° F. and a final temperature of 400° F. we should have a better thermal result than where, even with 3500° F. initial, we have 1200° F. final, the difference being as ·8 is to ·65.

Mr Anderson has, moreover, directed attention to the fact that the conductivity of substances varies inversely as the temperatures and probably as the absolute temperature, and hence the rate of transfer of heat to the water of a boiler will be slower in proportion at the furnace end than at the chimney end, but to what extent it is impossible to say, because the mean temperature of the boiler plates is unknown. It is probable, however, that it is below even the melting-point of lead, or 630° F. (as Mr Anderson remarks), because lead safety-plugs are frequently used even in locomotives, and they do not melt out unless there be a want of water. He says, "if we assume the mean temperature of the plates at the furnace end to be 500°, and that of the chimney end to be 350°, then the rate of transmission at the cooler end will be

about 18 per cent. greater than at the hotter. Were it not for the imperfect absorption of radiant heat and reduced conductivity caused by the high temperature, ebullition over and about the furnace would be so violent that uncontrollable priming would surely take place." This also serves to explain how a better result may be obtained with the moderate heat of a gas flame with cold air than with the hotter fire; and it further shows that in order to secure economy we must consider other elements besides the mere heat of the fire. It follows directly from these facts that higher temperatures of combustion demand greatly increased surfaces for transmission of heat to the water, or a longer period of contact of the flame and hot gases therewith, in order to reduce the temperature of the exit gases, so as to obtain the largest useful effect from the thermic cycle of operations.

Regarding the amount of evaporation which can economically be obtained from the heating-surface of boilers, Mr W. Anderson estimates that in practice 12 square feet of flue-heating-surface, measuring only the half over the gases, or 10 square feet of small tube surface, measured in the same way, will transmit the heat necessary to evaporate 1 cubic foot of water (= 62lbs.) per hour from and at 212°, which he reckons as one boiler horse-power; and that where the escaping gases have a temperature of 400° F., a mean velocity of 10·8 feet per second over the surface is admissible for them, which corresponds to 10 square inches of flue section per boiler horse-power, for a consumption of 1 lb of coal to 10 lbs. of water converted into steam.

Mr Thomas Box, in his "Treatise on Heat" (London: Spon, 2nd ed. 1876, pp. 85, 86), takes ⅔rds of a cubic foot, or say 40 lbs., of water evaporated from 60° into steam of any pressure as equivalent to one *indicated* horse-power, and gives a formula and table showing that in boilers of fifty horse-power and upwards, about 10·6 square feet of effective heating-surface are required for this work. This is equivalent to an evaporation of 4 lbs. of water from each square foot of heating-surface, and also if 8 lbs. of water are evaporated per lb. of coal, to a consumption of ½ lb. of coal per square foot of effective heating surface.

Mr D. Dixon, engineer to Messrs Gadsden & Co. of New York, who had considerable experience in this application of gas firing,

arrived at similar conclusions, and his observations have been, by the courtesy of Mr H. A. Gadsden, placed at the author's disposal.

Mr Dixon remarks that the conclusions to be drawn from their experience are:—

"1st. That more water can be evaporated per square foot of heating surface with hand-firing than by gas, unless the air is heated, so that as high a temperature is obtained with gas as can be derived from a coal fire; the amount of evaporation depending on the temperature and not so much on the volume of the heating gases." In this conclusion, Mr Dixon, however, does not take into account the relation of extent of surface to the temperature, initial and final, of the gases, and it is, therefore, not universally true.

"2nd. That if an evaporation of more than 7 lbs. of water per square foot of effective heating surface is obtained by gas-firing, it is at an enormous expense of fuel in proportion to the increase. All the data at hand lead to the conclusion that 4 lbs. per square foot is the most economical quantity at which to work a boiler." Mr Dixon adds, "This holds good as well in the case of hand-firing."

3rd. "Brick burners give a better result than iron ones. It is most important that combustion should be complete before the gases touch the boiler. An arch built over the burners underneath the boiler, extending back 3 or 4 feet, for the gases to burn against, is very effective; a few holes can be left in it to allow a little heat to pass through. The arch, when heated, acts as a sort of regulator."

"A combustion chamber built out in front of the boiler is effective, especially with a tubular boiler—or a deep combustion chamber, with the point of mixture of gas and air not less than 6 feet from the under-surface of the boiler." These conclusions were arrived at in the year 1883 as the result of several trials of gas-firing which were carried out in America, and will be described subsequently in this paper.

The firing of the steam-boilers in ironworks was one of the first uses to which the gases from blast furnaces were put, as soon as

their recovery was commenced. An ordinary method of carrying out this application of gas fuel to boilers is illustrated in Figs. 1, 2, 3.

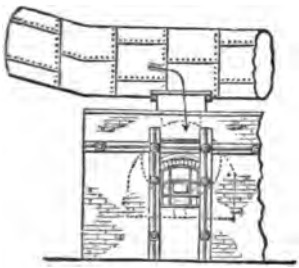


FIG. 1.

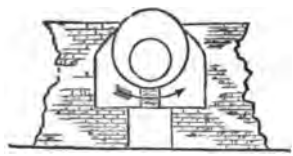


FIG. 2.

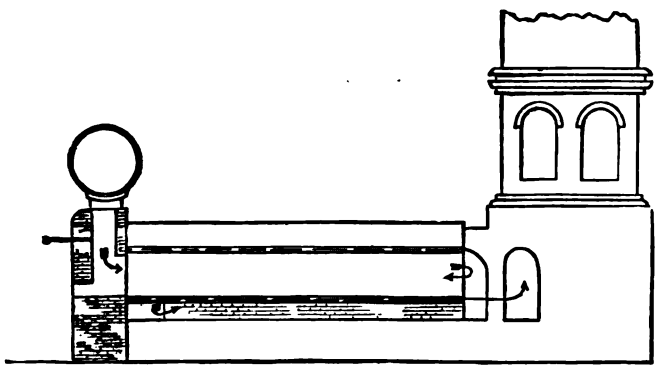


FIG. 3.

The gas is usually conveyed to the front of the boilers by overhead mains, with vertical branches leading downward, as is shown. The air for combustion is generally admitted through gratings or other openings in the furnace door, through which it is drawn by the draught of a chimney, but it is sometimes supplied from a fan or blowing engine, by means of a blast-pipe leading into the furnace or ash-pit. In order that the gas should be always ignited, some solid fuel is usually kept burning near the gas and air inlets. The experience gained in such ironworks with this system of firing boilers showed its advantages in some respects. Repairs to the boilers were lessened, and the life of the boilers was prolonged, whilst their steaming power was increased. The

economy of fuel, as compared with hand-firing with solid fuel, could not be investigated, for the simple reason that the quantity of gases used could not be measured. To the ironmaster, however, the use of the waste gases in this way was wholly an economy—a waste product completely taking the place of so much coal or dross.

Some of the earliest comparative trials of gas-firing applied to boilers, of which we have records, were carried out in France. Many attempts had been made, both in France and in Britain, * to introduce forms of apparatus or arrangements of furnaces by which the formation of smoke would be prevented—or, as they were termed in those days, smoke-consuming apparatus. These experiments, no doubt, paved the way for the introduction of

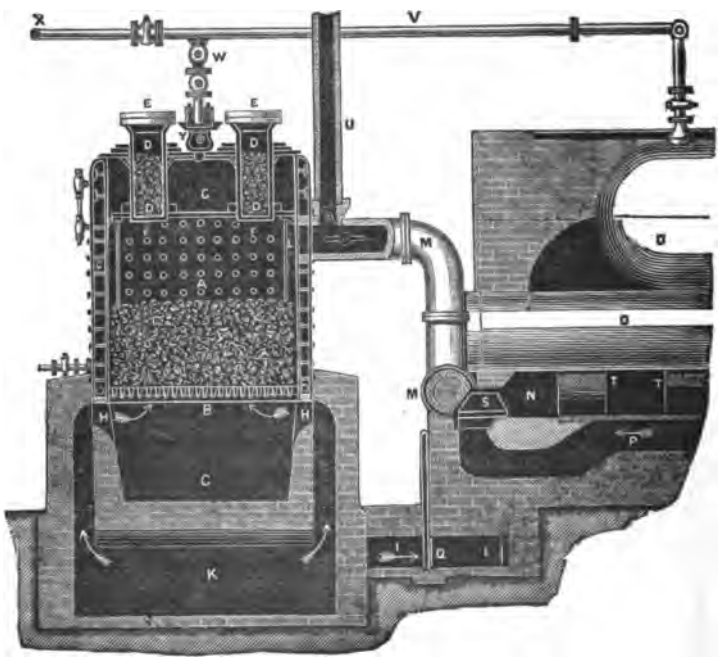


FIG. 4.

* See Notice sur les Appareils fumivores, appliqués aux Foyers des Machines-à-vapeur et notamment aux Machines locomotives employant la Houille, par M. Turck : *Mém. et Compt. Rend. de la Soc. des Ingén. Civils*, No. 36, pp. 585-628 (Paris, 1866.)

gas-firing, the earliest apparatus designed for this system as applied to steam boilers having been that of M. Beaufumé. The gas-producing part of this apparatus has been already described by the author (see "On Gas Producers," Min. Proc. Inst. C.E., vol. lxxxiv. pp. 11-13.) Figs. 4 and 5 show the combustion arrangements in connection with the boiler setting.

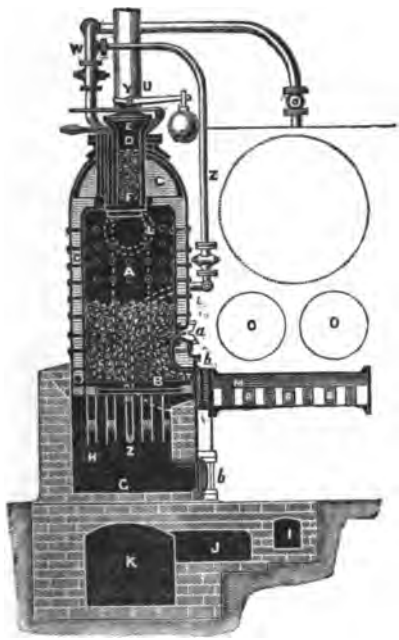


FIG. 5.

The late Professor Macquorn Rankine, in October, 1857, communicated to the Institution of Engineers in Scotland,* the results of experiments made with the Beaufumé apparatus, which proved its practical usefulness.

The following table gives the results of the experiments made at the Imperial Arsenal at Cherbourg by order of the French Government, under the supervision of MM. Guesnet, Admiralty Engineer, and Sochet, Director of Naval Construction, by whom a report was issued.

* "Trans. Inst. Eng. in Scotland," vol. i. pp. 14-18.

Four series of experiments were made, the first three being with the boiler of the establishment called the Northern Forge at

Results of Experiments made at Cherbourg.

No.	Date.	Duration of Experiments.	Total Amount of Fuel Consumed.	Kind of Fuel.	Water Evaporated. During the Experiment.	Water Evaporated. Per Hour.	Water Evaporated. Per lb. of Coal.	Observations.
	1856.	H. M.	Lbs.		Lbs.	Lbs.	Lbs.	
								Series No. 1.
1	May 7	8 30	970½	Large Newcastle Coal	4,620	543·5	4·865	The boiler of the forge heated by the ordinary furnace.
2	,, 8	8 31	1,014½		4,905	561·9	4·835	
								Series No. 2.
3	,, 28	8 45	908½	Large Newcastle Coal	5,640	644·4	6·210	The boiler of the forge heated by the Beaufumé apparatus.
4	,, 29	8 30	1,058½		7,110	836·5	6·710	
5	,, 30	8 30	1,021		6,621	778·5	8·260	
								Series No. 3.
6	June 2	8 30	847	Small Coal, (Cardiff, Newall's, Llanelly)	6,131	875·6	7·240	The boiler of the forge heated by the Beaufumé apparatus.
7	,, 4	8 30	811½		6,744	791·8	8·300	
8	,, 6	8 0	761		5,518	689·7	7·250	
								Series No. 4.
9	,, 12	7 0	1,500	Newcastle Coal	12,751	1,821·6	9·035	*Weather Cold.* A tubular boiler heated by the Beaufumé apparatus.
10	,, 15	5 15	849		7,353	1,400·4	8·066	
11	,, 16	7 15	1,235		12,218	1,676·2	9·820	
12	,, 17	7 0	1,235		11,618	1,659·7	9·407	
13	,, 18	6 0	1,058½		9,788	1,631·3	9·245	
14	,, 23	5 0	1,058½		9,420	1,884·0	8·897	*Weather Temperate* 36 out of 106 tubes closed.
15	,, 25	9 0	2,029		17,719	1,969·5	9·038	
16	,, 26	2 30	4,762		6,921	1,885·7	9·898	42 out of 106 tubes closed.
17	,, 29	3 45	653		6,923	1,864·0	10·600	

Cherbourg. This boiler (of 12 h.-p.), had 167½ square feet of heating surface, and its ordinary grate surface was 12¼ square feet.

The Beaufumé gasifier had a grate surface of 5¼ square feet, the fuel being allowed to be 27½ inches thick on the grate. The gasifier was 11½ feet high, and measured 10 feet by 6½ feet on its width and depth respectively.

The fan delivering the air-supply was driven at one thousand revolutions per minute, and supplied the blast at a pressure of 1·97 inch of water.

The fourth series of experiments was made with one of four tubular boilers lying in the boiler-yard at Cherbourg ready for the steamer *Antelope*.

MM. Guesnet and Sochet certified that, although there were some inconveniences connected with the system, yet the apparatus worked with great regularity; no smoke was made, and a saving of 38 per cent. was realised. They estimated the saving which might be reckoned upon with certainty in ordinary work at 33⅓ per cent.

Professor Rankine supplied some additional details not given in the report—viz.: In all the experiments the water supplied to the boiler was cold; and as it is usual to reduce the results of experiments of this kind to the results which would have been obtained if the boiler had been supplied with water at a temperature of 212° F., 18 per cent. must be added to the evaporation in series 1, 2, and 3, and 16 per cent. to that of 4; this making the results in one case 9·8 lbs., and in the other 10·5 lbs. of water evaporated per lb. of coal. In other experiments, one of the best results obtained, when water of about 100° was supplied, was equivalent to an evaporation of nearly 12 lbs. of water from 212° per lb. of coal.

The boiler used in the first three series of experiments was evidently a bad one, because its usual rate of evaporation, when coal was burned on the ordinary grate, was only 4·85 lbs.

The Siemen's gas producer, which was introduced about the same time as Beaufumé's, was also applied to boiler firing, but we

have no published record of results of this application of it. It has not proved itself so well suited for this class of furnaces as for others.

At a very early period the late Mr W. Gorman worked in this direction, and in his first paper, "On the Combustion of Coal,"* described experiments which showed the advantage in economy of fuel to be obtained from the use of even a modified form of gas-firing. The apparatus he employed was an ordinary steam-boiler furnace, with a closed ash-pit, having blast delivered under the furnace bars and through openings in the interior surface of the double casing of the furnace door.

With ordinary air supply and chimney draught, the same furnace and boiler using 28 lbs. of coal evaporated 93 lbs. of water, whilst with the blast applied and firing arranged on Mr Gorman's system, the same weight of coal evaporated 110 and 123 lbs. of water on different occasions. Mr Gorman displayed an intimate acquaintance with the processes of combustion, and in this paper foreshadowed the further developments in the direction of gas production, which were soon introduced.

M. E. Minary, an engineer of Besançon, published in 1868† an elaborate treatise on combustion in manufacturing furnaces, in which, after explaining the general principles and chemical reactions connected with combustion, he described the construction and the action of his "apparatus for double combustion," as he called it, which was a gas producer with mechanical air supply, both for combustion in the producer and for combustion of the gas in the furnace. A description of the gas-producing part of his apparatus will be found in the author's paper on "Gas Producers" (see Min. Proc. Inst. C.E., vol. lxxxiv., pp. 18-20); and in Fig. 6, the arrangement of gas producer with grate bars and closed ash-pit, and forced air supply for the double combustion, as applied to a French boiler, or *chaudière à bouilleurs*, is shown.

M. Minary's general conclusions on the subject of combustion

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* "Trans. Inst. Eng. in Scotland," vol. ii., pp. 70-80, and plate vi.

† *Publication industrielle des Machines outils et appareils*, &c., vol. xviii. (Paris, 1868).

are curious and interesting. He thus enumerates them :—

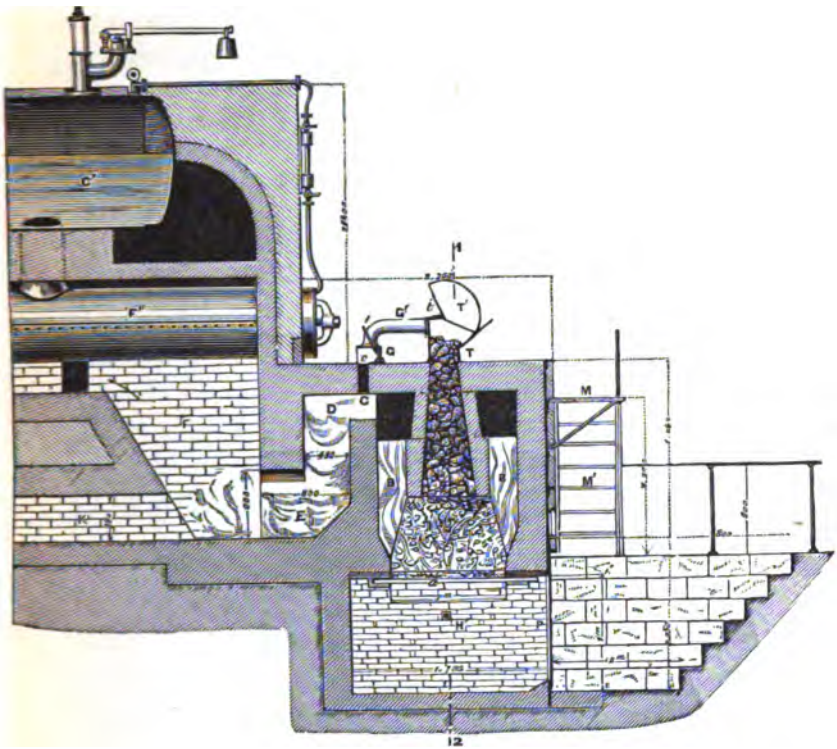

FIG. 6.

1. In all furnaces the transmission of heat is primarily due mainly to contact of the hot gases with the fuel, with the walls of the furnace, and with the heating surface of the boilers.

2. The radiation of fires is only a reflex action, following the anterior transmission of heat by the contact of the gas.

3. It could only be otherwise for combustible bodies whose products of combustion are not gaseous, such as iron and certain metals, the oxides produced having a considerable power of radiation.

Regarding the utilization of the heat of furnaces, he concludes that :—

1. The apparatus in which combustion takes place should be perfectly distinct from the one in which the heat is utilized.

2. This apparatus should be preserved from cooling by a thickness of walls sufficient to minimise the loss of heat outwards.

3. The maintenance of a high temperature in the combustion chamber is a guarantee of perfect combustion of the gas, and it is consequently necessary to avoid reducing it for the deceptive advantage that the radiation from the gas might produce.

4. The gases escaping under these conditions from the combustion chamber at a temperature so much higher than it, suffer no loss of radiation, as they take with them all the heat that has been produced, and as they are in contact with the surfaces of the generators we can recover thus nearly all the heat which the fuel can give.

M. A. Fichet* made many experiments and trials in the course of his investigation of this subject, and communicated the practical results, when he had attained to an assured success, to the French Institution of Civil Engineers.

M. Fichet at first endeavoured to apply to boiler-firing, with merely some modifications in details, the arrangements of gas producers and combustion chambers which he had already introduced with good results in gas-works. He found, however, that the rapid cooling of the flame and hot gases by contact with the boiler surfaces, produced phenomena which necessitated a complete change in his combustion apparatus. When using non-bituminous fuel and admitting for combustion of the gas a very slight excess of air above the theoretical quantity, the flame was extinguished on contact with the boiler surfaces; but analysis of the waste gases showed the presence of both free oxygen and carbonic oxide, proving that the gas had not been completely burned. With caking coals smoke was produced, in addition to these unsatisfactory results; but in the arrangements for firing gas retorts, these difficulties had not been encountered. Trials were therefore made of successive forms and arrangements of

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*Études sur la Combustion et sur la Construction rationelle des Foyers industrielles, Par A. Fichet: *Mém. et Compt.-Rend. des. Travaux de la Soc. des Ingén. civils*, 1874, pp. 670-711 (Paris).

combustion apparatus, and the nature of the products of combustion was always observed by analysis, so that the completeness of combustion in each case was estimated. The calorific value of the gas from the generator was also measured by the calorimeter and compared with the actual result of combustion. By these means, M. Fichet arrived at various general conclusions on the subject of the combustion of fuel, which are given in his interesting memoir, and at a form of apparatus for boiler firing, which worked successfully, giving, as he says, complete combustion without excess of air being mixed with the products of combustion. The principles on which this apparatus rests are given as follows :—They consist in intimately mixing at a high temperature the combustible gases and air, both being divided up into thin streams, this mixing taking place in a chamber built of refractory material in which combustion (or rather inflammation) must be allowed to be complete ; and, in allowing this completed mixture of gas and air to come in contact with the boiler surfaces only when its inflammation was complete, and nothing remained but to utilize the heat which was thus being produced.

Three types of this arrangement were successfully introduced —viz., as applied to a French boiler with feed-heaters (*chaudière à bouilleurs et réchauffeurs*), to a cylindrical boiler with internal furnace, and to a vertical boiler with "Field" tubes. Figs. 7 and 8

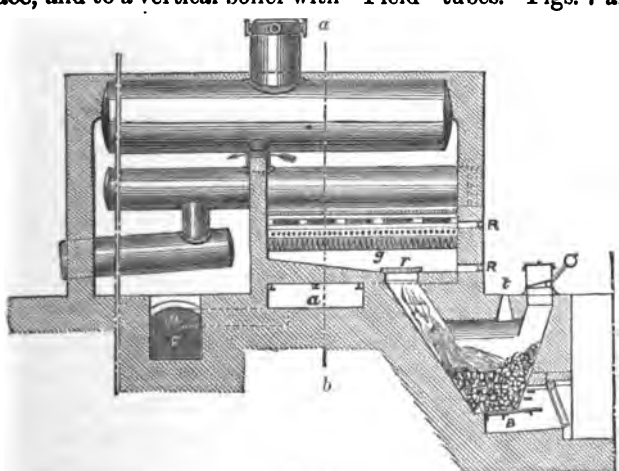


FIG. 7.

show the first of these types, Fig 7 being a horizontal section on the line *cd* of Fig. 8. and Fig. 8 being a vertical section on the line *ab* of Fig. 7.

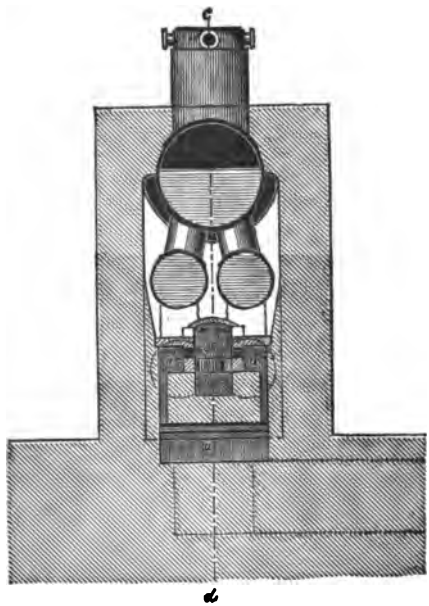


FIG. 8.

The first trials with this type of boiler were made at the works of M. E. Muller at Ivry.

The cylindrical portion of the boilers used was 3 feet 7 inches (1 m. 10) in diameter, with heaters or accessory chambers 24 inches (60 centim.) diameter—the lengths are not given—and having a heating surface of 560 square feet (52 square mètres), not reckoning the surface of the feed-water heaters. A producer, in the form of a modified Siemens sloping grate, of which A was the fuel chamber and B the ashpit, was placed in front of the boiler, below the floor level. The fuel was charged every hour in quantities of about 2 cwts., by means of the charging box and cover shown. Air was admitted to the grate through perforations in the double swing-door shown at the entrance to the ashpit. The gases produced from the fuel ascended by an

inclined passage into the chamber *g* (Fig. 7) below the boiler, their rate of admission to this chamber being regulated by a damper *r*. The roof of the chamber *g* was constructed of flat pieces of firebrick, arranged to form a grating, which provided a number of narrow openings for the escape of the gas into the combustion chamber *c* above, see Fig. 8. The air for combustion was supplied by the pipe *a*, Fig. 7, laid in the chimney flue F, in which it was heated by the hot waste gases. This pipe led into the chamber *a*, below the gas chamber *g*, from which the air ascended by passages on each side of *g*, see Fig. 8, meeting the gas in *c*, where combustion commenced. The heat imparted to the air in the pipe *a* and subsequently in the chamber *a* and passages on either side of the gas chamber, caused it to issue from the orifices into *c* with considerable velocity. It was divided into thin streams, and met the streams of gas issuing in a different direction, thus causing a thorough mixture. Although this arrangement worked well and gave good results, yet analysis of the waste gases always showed the presence of free oxygen, which was due to the admission of a slight excess of air. This excess was at last traced to leakage of air through the pores of the bricks composing the building of the boiler setting and the combustion chamber, when it did not gain admission by cracked seams formed by contraction during drying. The chimney draught sufficed to produce this filtration of air through the furnace walls, even when the air supply was delivered from a blower.

A boiler of the same dimensions, but fired by an ordinary grate, placed alongside the gas-fired boiler and supplied with the same coal and water, gave the means of instituting a comparison between the two methods of working. The boiler with ordinary grate evaporated almost constantly about 6 lbs. of water per lb. of coal, the coal being the ordinary bituminous kind of the North of France and of Belgium. This rate of evaporation, M. Fichet remarks, is in accord with that obtained from the experiments carried out at Wesserling and Winterthur, and published in the *Bulletin de la Société industrielle de Mulhouse* in 1873.

The gas-fired boiler showed an evaporation of from 8·6 to 9·2 lbs. of water per lb. of coal. This, M. Fichet remarks, is equal to an increase of useful effect amounting to 48 per cent., or,

otherwise, to an economy of 32 per cent. for an equal production of steam.

The feed-heaters of the Ivry boiler had not a sufficient amount of heating surface to cool the waste gases below 225° C. (437° F.)

Fig. 9 shows the arrangement for boilers with internal furnace,

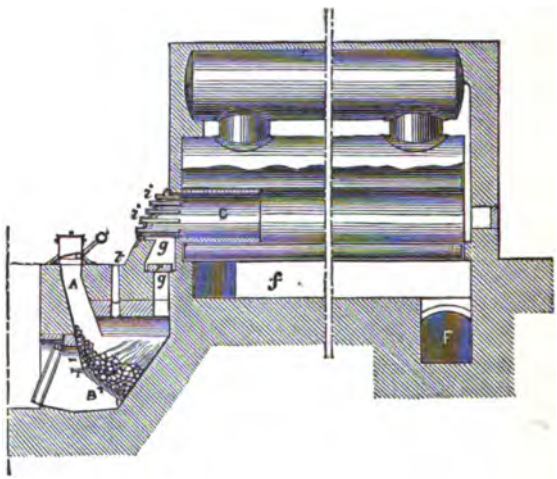


FIG. 9.

C being the combustion chamber, and *i i i i* numerous openings in an inclined door lined with firebrick, which closes the outer end of the chamber C. The openings *i i* are formed by wrought-iron tubes, which conduct the air into C; in this case the chimney draught was relied upon to carry the supply of air into the combustion chamber.

The arrangement for one class of vertical boilers is shown in Fig. 10. The gas descends by the passage *g* and the damper *r*, and, meeting the fire-brick cover *d*, it escapes by horizontal openings into the combustion space *c*, into which also air is delivered from a series of orifices connected with an annular passage *a*.

No results are given of the working of boilers of the two latter types, but M. Fichet gives the tables showing the details of continuous working for a week with the French boiler, which were reproduced in the author's former paper on this subject read to this Institute.

M. Fichet has remarked that these tables exhibit some anomalies, which are specially noticeable at the commencement of

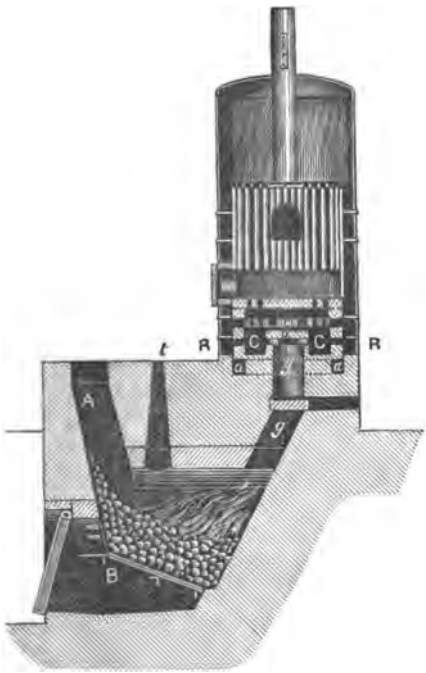


FIG. 10.

the week's work, in consequence of some imperfections in the apparatus then used. He did not correct these errors, as they did not affect the final result, which was as follows :—

Coal burned in one week during working hours,	5,540	kilos.
Water evaporated during the same time, ...	50,088	„
Showing mean quantity of water evaporated per kilogramme of coal burned, =	9·04	„

During the night at first, in consequence of leakage of steam and gases from the boiler and setting, 377 kilos. (about 7 cwts.) of coal were burned uselessly. He succeeded, however, latterly in bringing this down to 80 kilos. (about 1½ cwts.), but even that was an unnecessary waste.

Mr D. K. Clark remarks* that "M. Fichet states, as the result of numerous observations, that in the gases supplied by the gasogene there are frequently not any traces of carbonic acid, sometimes ½ per cent., rarely 1 per cent. In the gaseous products of combustion there is not a trace of free carbonic oxide, and often there is not a trace of free oxygen. For the strongly bituminous coals, however, it is necessary to admit an excess of oxygen, of from 1 to 1½ per cent., to ensure the complete absence of smoke. This proportion of free oxygen represents an excess of air amounting to from 4 to 6½ per cent."

It is said that the plans of Messrs Muller and Fichet were experimentally tried in Upper Silesia, at Dortmund, and at Essen, but that objections were urged against them on the score of frequent repairs being necessary. Consequently the plan illustrated in Figs. 11 and 12 was introduced by Herr A. Hartmann.†

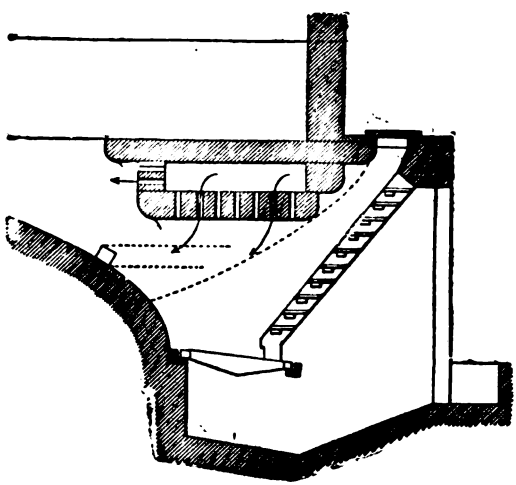


FIG. 11.

In this plan the fuel was introduced through a filling-hole at the floor level in front of the boiler, and covered an inclined

* "Fuel, its Combustion and Economy," p. 251.

† See "Engineering," Jan. 2, 1880.

step-grate to a thickness of 6 to 8 inches, reaching a thickness of about 14 inches on the bottom part of the grate, which was level.

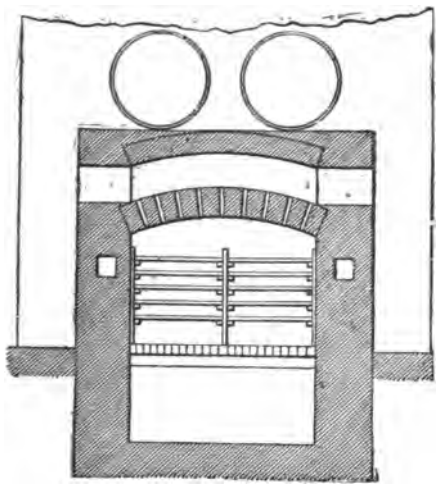


FIG. 12.

The form of the bars on the inclined slope prevented the fuel falling through to the ashpit, and enabled very small coal to be used. Two concentric arches were built over the producer, having a channel for air between them, the lower one having openings pierced through it for admitting the air to the gas chamber. The current of air kept the perforated arch cool and prevented its rapid destruction by the heat of combustion.

Herr Haupt of Brieg,* in Silesia, devoted much study to this question, and in particular endeavoured to simplify the construction of the producer and to arrive at the best method of mixing the gas and air together.

His first experiments were "undertaken† to determine the best means for bringing the gas and air into contact; and Figs.

* *Chemiker Zeitung* for 1880, p. 290.
† "Engineering," Jan. 2, 1880, p. 3.

13, 14, 15, 16, and 17 show different stages by which he

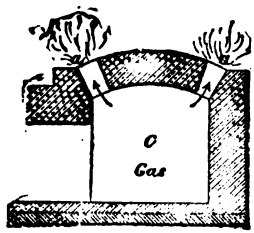


FIG. 13.

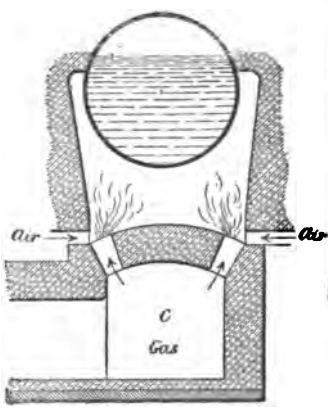


FIG. 14.

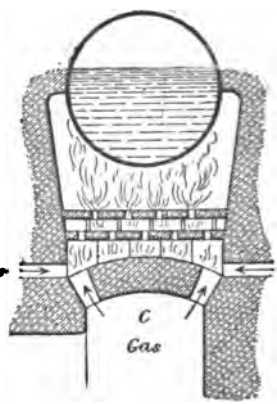


FIG. 15.

arrived at the most favourable results, Figs. 14 and 15 representing two different arrangements of fire-brick arches used for obtaining thorough mixture of the gas and air."

"The distance from the bottom of the boiler to the top of the fire arch was found to exercise a very marked influence on the results obtained, the most suitable distance having been found experimentally to be about 22 inches to 24 inches. The arrangement shown in Fig. 15 was worked day and night for six weeks with small coal from the Florentine pit in Upper Silesia, and the

evaporation obtained per pound of coal was equivalent to 8·4 lbs. of water at atmospheric pressure from feed water at 32° F."

FIG. 16.

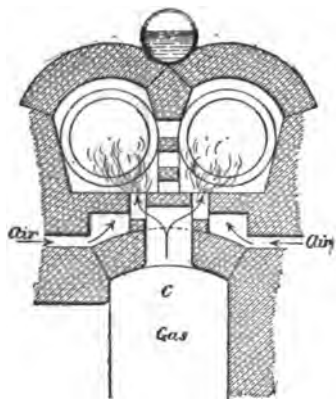


FIG. 17.

With caking coal an evaporation of 9·6 lbs. of water was obtained. These results led to trials of a modification of the plans as applied to two boilers belonging to the Lower Silesian Mining Union, which were used for experimentally determining the evaporative powers of different kinds of coal.

Figs. 18, 19, 20, and 21 show the modifications which were adopted in this case.

In these plans, *G* is a separate gas producer, with grate-bars and charging hopper with cup and cone, the air supply of which was forced in under the grate by a Körting blower by the pipe *K*, after having been heated by passing through tubes in the sides and bottom of the producer brickwork. This air attained a temperature of 185° to 194° F. Fig. 18 shows a longtitudinal elevation in section, and Fig. 19 a sectional plan. *v* is a gas valve, *C* the gas flue, and *f* is a torch-hole used for lighting the gas at starting. Under the boiler, the gas-flue *C* is arched over by bricks, *Z*, leaving alternate spaces for gas exits. The air for

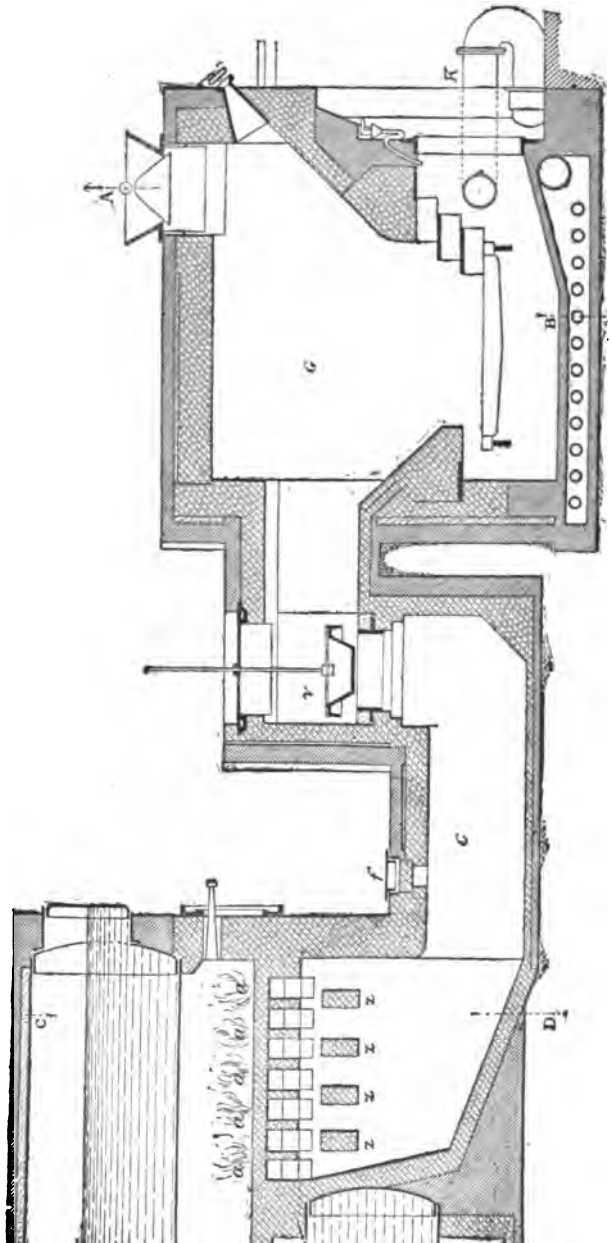


FIG. 18.

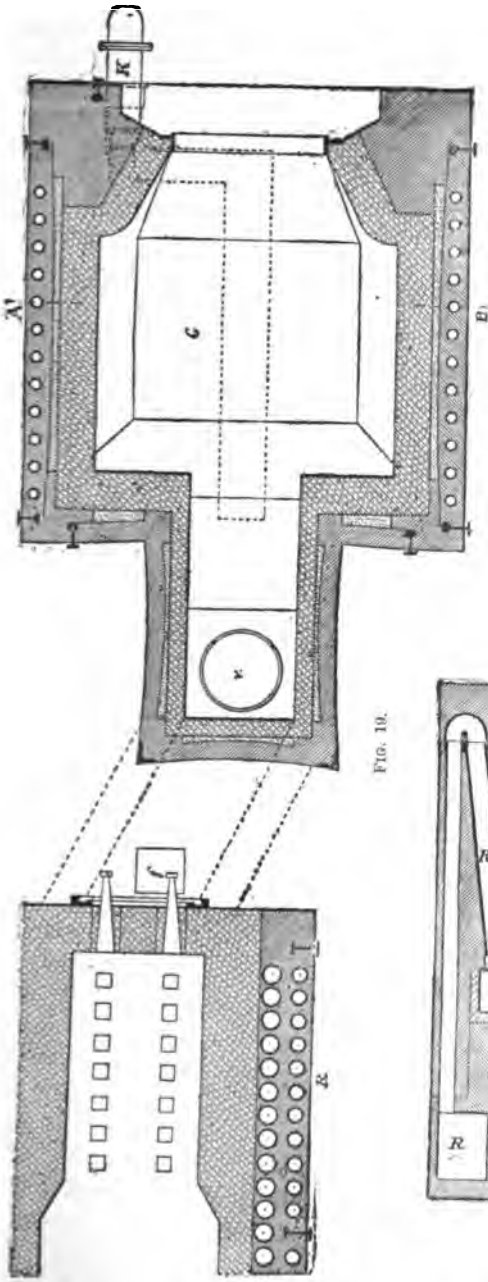


FIG. 19.

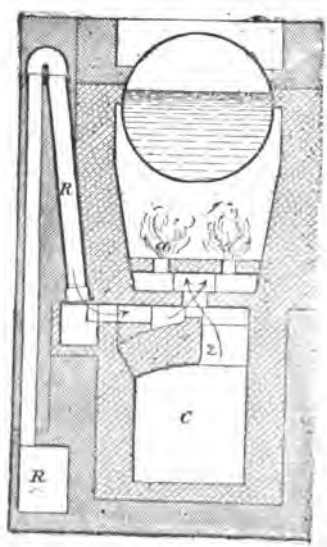


FIG. 20.

combustion is heated in the vertical pipes *R* (Figs. 19, 20), which it reaches from the passage *R* (Fig 19). It passes horizontally over *Z* to meet the gas, and the mixture burns at the openings *a a a a.*

On account of want of space from the proximity of the next boiler, the one-sided combustion arrangement shown in cross section in Fig. 19 was adopted, but had soon to give way to the

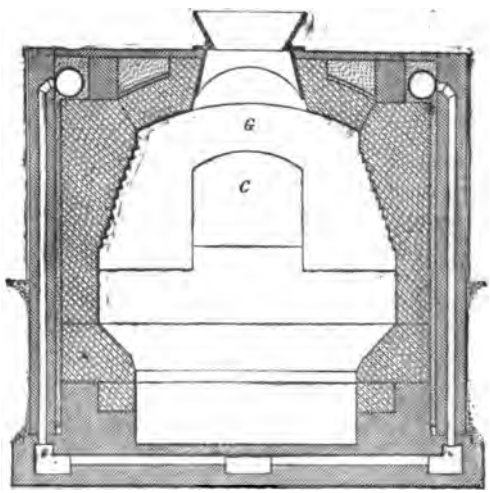


FIG. 21.

alteration shown in Fig. 22. "It was observed that the maxi-

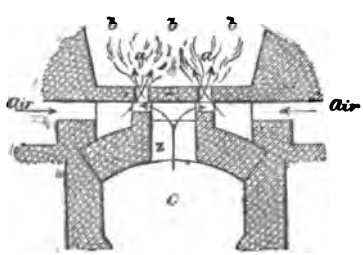


FIG. 22.

mum temperature was produced about *a a* in Fig. 22, and that at

b b it had decreased to about 1770 degrees F. This fact accounts for the durability of the fire-brick arches, as well as for the immunity of the bottom of the boiler from injury." Several

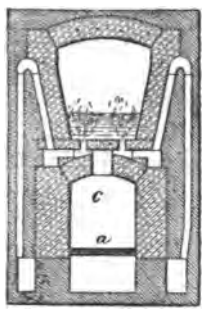


FIG. 23.

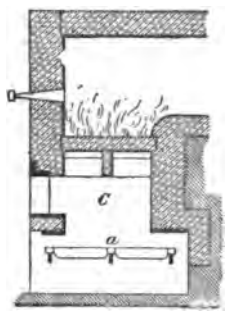


FIG. 24.

difficulties were met with in the management of the producer; but these were due partly to frequent changes in the quality of coal used—different kinds being experimented with—and partly to the producer having been worked with air blast alone. The method of lighting the gas also introduced difficulties, as, in spite of the exercise of great care, explosions occurred. This was probably the result of placing the lighting-hole *f* badly. The proper position would seem to be above *a a*, where the sight-holes are placed, for here the air and gas are mixed, and the flame cannot flash back below the upper side of the arches *z*.

"In order to arrive practically at the best form and proportions for the producer of a new and simpler kind, experimental-furnaces (shown in Figs. 23 and 24), were built, the bottom of the fire-arch being kept at a distance of about 2 feet above the grate level. Several kinds of fuel were tried, some containing as much as 50 to 60 per cent. of ash, as well as the mud remaining in the coal-washing machines; but even with these very unfavourable fires it was impossible to choke the furnace."

Figs. 25 and 26 show the arrangement which was finally

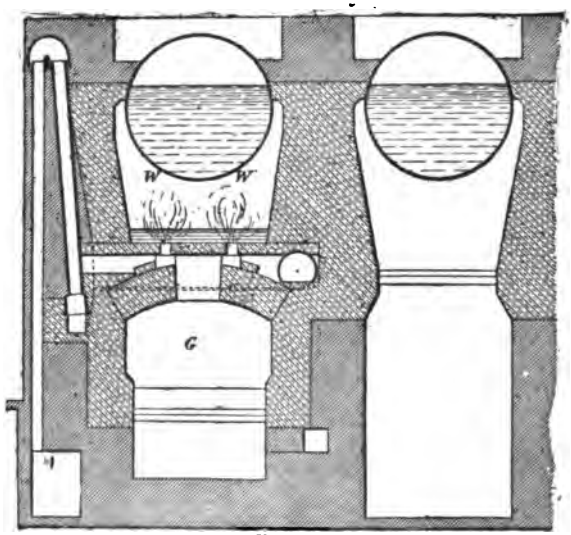


FIG. 25.

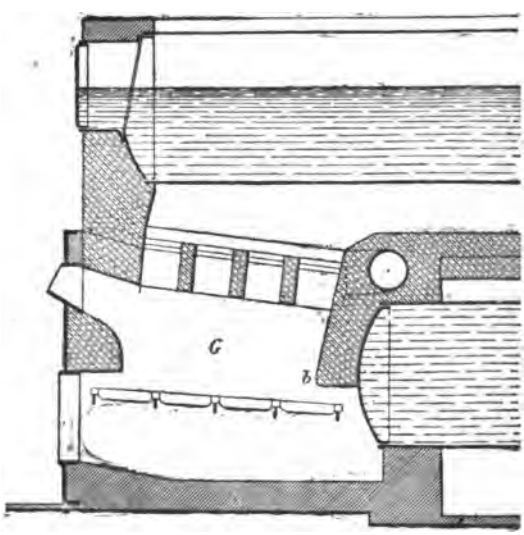


FIG. 26.

adopted, with which it was found possible to evaporate from 1½ to 2½ lbs. more water per lb. of coal than had been evaporated when the boiler was fired in the ordinary way, double the weight of steam being moreover produced in a given time.

"In a trial carried on for eleven hours, the coal-fired boiler evaporated about 11,000 lbs. of water at a pressure of 90 to 105 lbs. per square inch, the feed temperature being 50° F. The total heating surface exposed was 430 square feet, which gives, say, 2·325 lbs. of water evaporated per square foot of heating surface per hour. Under similar conditions the gas-fired boiler evaporated from 23,540 lbs. to 29,000 lbs. of water, or, say, from 4·41 to 5 lbs. per square foot of heating surface per hour; and even at this high rate of evaporation the temperature in the flue leading to the chimney never exceeded 662° F. The most rapid evaporation possible with the coal-fired boiler was 19,250 lbs.; but the temperature of the escaping gases then rose to 932° F., and the evaporation of water per lb. of coal diminished to 6 lbs. to 6½ lbs. The temperature at *W* (Fig. 25), just under the boiler surface, was found by Weinhold's pyrometer to be 2306° F., which

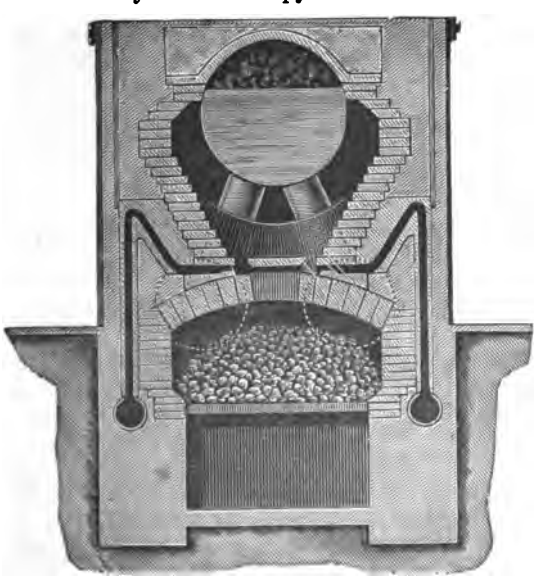


FIG. 27.

is considered to be below what is often produced under boilers fired in the ordinary way." After five months' work, the only place showing signs of wear was the fire-brick hanging bridge *b* (Fig. 26), which protected the end of the heater, the moderate wearing being considered to be due to the moderate temperature and uniformity of heating produced by the gas firing.

Figs. 27 and 28 show the most recent form of this arrangement for gas-firing.

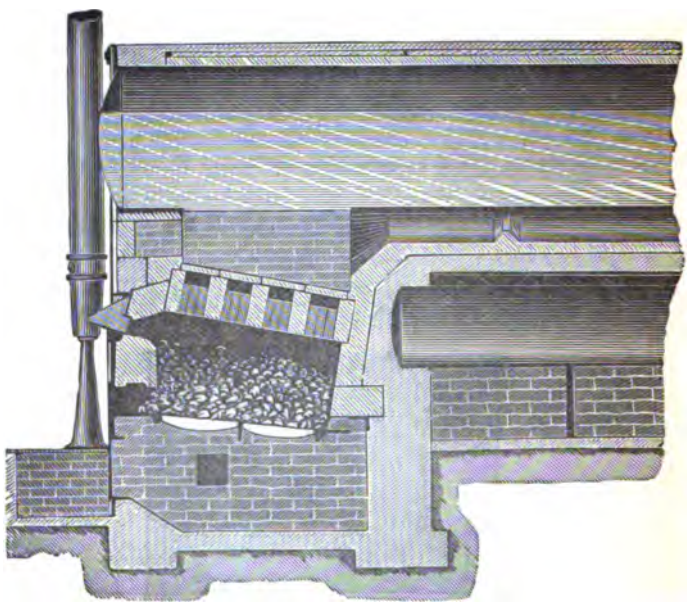


FIG. 28.

By this method the air for combustion is heated to from 280 deg. to 295 deg. C. by a simple arrangement of tubes. In the transverse section, Fig. 29, an inlet pipe of 10½ to 11 inches (265 to 285 mm.) diameter is shown extending along each side of the firing chamber. From these branch off small vertical tubes of 2½ to 3 inches diameter, their ends dipping downwards and ending in horizontal passages facing those from which the gas issues on its ascent through the roofing arch of the producer. The highest

temperature observed in the combustion chamber is stated to have

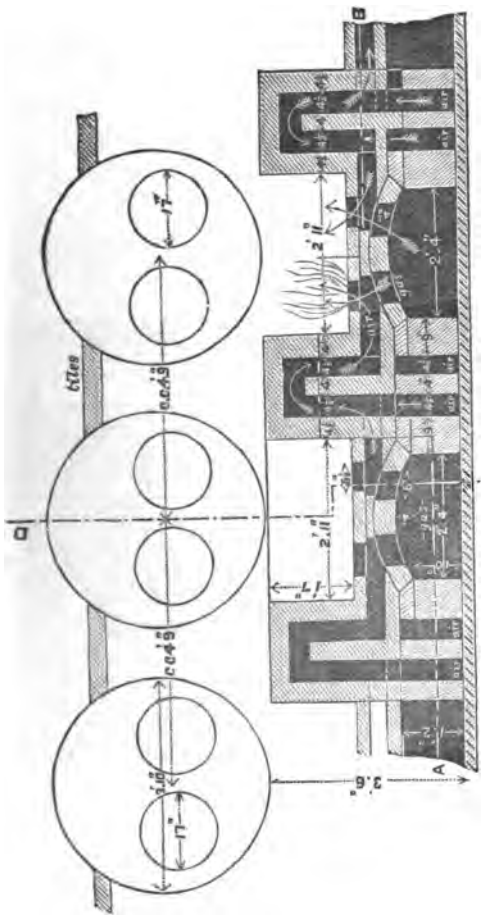


FIG. 29.

been 1039 deg. C. A Körting's blower is used, as shown in Fig. 30, which gives control of the fire, and (by means of the steam used in the blower) heats the air delivered from 6 deg. to 10 deg. The steam, as is well known, also acts favourably as regards gas

production, and with Haupt's apparatus a spray of water is sometimes also used under the grate in order to keep the bars cool.

Coal containing from 20 to 80 per cent. of ash, shale with 50 to 60 per cent. of ash, slack coal, small turf, tar, and lignite have been used as fuel. With coal from Lower Schleswig an evaporation of 8·7 lbs. of water per lb. of coal was obtained. With grate firing 10 to 12·06 kilos. were evaporated per square mètre of surface, whilst gas firing evaporated 19·85 kilos., and with Hungarian lignite as much as 22·08 kilos. With the lignite from

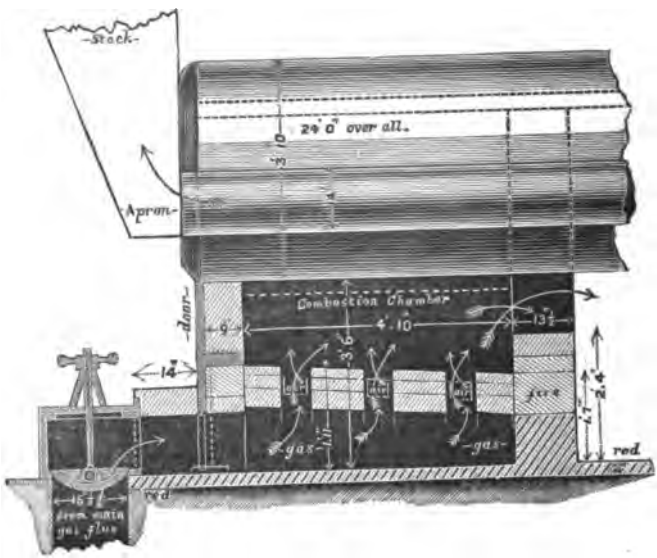


FIG. 30.

Edderitz, near Cöthen, the evaporation was increased 25·2 per cent. as compared with ordinary grate firing, and the useful effect of the boiler 64·7 per cent.

Similar experiments in the sugar refinery at Gutschdorf gave an economy of 38 per cent. of coal, whilst other experiments are said to have given 53 to 64 per cent.

Table of Comparative Results with Hand and Gas Firing.

	Boilers.		Boilers.		Boilers.		Boilers.		Boilers.		Boilers.	
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
Kilos. of coal burnt in 11 hours,	532	834	530	864	643	872	1,568	1,785	1,543	2,030	1,550	2,020
Kilos. of water evaporated in 11 hours from 0° to 100° C.,	4,438	8,224	4,629	8,354	5,305	8,735	6,284	9,716	4,016	6,619	4,174	6,567
Kilos. of water evaporated by 1 kilo. coal,	8·343	9·86	8·743	9·73	8·283	10·07	4·023	5·443	2·569	3·251	2·764	5·158
Temperature in cross flue,	237°	271°	233°	249°	239°	253°	332°	254°	244°	223°	240°	225°
Do. in combustion chamber,	930°	1011°	916°	1018°	911°	1002°	890°	933°	870°	920°	860°	915°
Percentage of carbonic acid in cross flue,	8·0	14·9	11·1	13·9	9·1	13·9	8·9	13·1	8·3	13·3	8·7	12·5
Kilos. of water evaporated per sq. met. of surface per hour,	10·09	18·69	10·52	18·99	12·06	19·85	14·28	22·08	9·13	15·04	8·7	14·22
Rise of effect of coal,	—	18%	—	12%	—	20%	—	35%	—	25.2%	—	14·3%
Do. absolute effect of boiler,	—	85°/.	—	80°/.	—	64°/.	—	54%	—	64·7%	—	63·4%

The waste gases contained 2 to 3 per cent. of free oxygen, 0·1 to 0·3 per cent. of carbonic oxide, and 12·5 to 14·7 per cent. of carbonic acid. The quantity of soot and dust in the flues was found to be nine times more with grate firing than with this system, and a smaller amount of chimney draught was sufficient. With a separate producer the deposit of soot and dust in the boiler flues may be altogether prevented.

The table on p. 89 gives results of trials carried out at the experimental station at Brieg, No. I. being a boiler with grate fired in the ordinary way, and No. II a boiler fitted with gas firing. Each boiler had 40 square mètres of heating surface, and the draught in both cases was alike. The steam pressure, also in both cases, was 6 to 7 atmospheres.

The interesting report of experiments carried out by Mr J. H. Darby at Plas Power Colliery, Wrexham, is given in the author's former paper to this Institute (Vol. V. p. 229). The following table shows the principal evaporative results :—

	No. 1 Trial.			No. 2 Trial.			No. 3 Trial.		
	Lbs. of Water Evaporated by 1 lb. of Fuel, Feed Water at 100° C., Steam at Atmospheric Pressure.	Lbs. of Water Evaporated by 1 lb. of Fuel.	Water Evaporated per Hour in lbs.	Lbs. of Water Evaporated by 1 lb. of Fuel, Feed Water at 100° C., Steam at Atmospheric Pressure.	Lbs. of Water Evaporated by 1 lb. of Fuel.	Water Evaporated per Hour in Lbs.	Lbs. of Water Evaporated by 1 lb. of Fuel, Feed Water at 100° C., Steam at Atmospheric Pressure.	Lbs. of Water Evaporated by 1 Lb. of Fuel.	Water Evaporated per Hour in Lbs.
No. 1 Boiler (gas)	6·86	5·8	4,357	7·8	6·5	4,204	10·33	8·6	3,768
No. 2 Boiler . .	6·26	5·3	2,965	7·5	6·3	3,145	9·49	7·9	3,280

In summing up the results of these tests, Mr Darby remarked that the gas-fired boiler was under considerable disadvantage

through all the trials, owing to only one producer being at work to supply it, the quantity and composition of the gases varying so much from one addition of fuel to another that it was almost impossible to regulate the supply of air for combustion to the adequate amount. If several producers had been working together, the duty done by the fuel would have been better. On the other hand, the hand firing in the Nos. 2 and 3 trials could not be improved upon, as the greatest care was taken.

The gas-fired boiler making 32% more steam than the hand-fired boilers in a given time, or after deducting the steam used by the steam jet, which was equal to 170 lbs. of water per hour, gave 26·9% more duty. Therefore, five producers, four working and one off for cleaning, would make all the steam required for seven boilers.

Some interesting results of the application of natural gas to boiler firing are given by Mr A. Carnegie in his paper on Natural Gas in the Journal of the Iron and Steel Inst., vol. i. 1885, p. 174.

Other results of gas-firing will be found noted in Trans. Mining Inst. of Scotland, vol. vii., pp. 57 and 162, and in the Report of Mr D. K. Clark to the Committee of the Smoke Abatement Exhibition (published by Smith, Elder & Co., London).

The table on p. 92 gives the results of careful observations of gas firing trials carried out with boilers 30 feet long and 7 feet diameter, with 2 feet 8 inches diameter of flues, supplied with gas from separate producers :—

RESULTS OF TRIALS OF GAS FIRING APPLIED TO STEAM BOILERS.

Date of Trials, 1884.	Duration of Trial in Hours.	Class of Fuel.	Height of Fuel in Producer from Bottom of Casing: Feet.	Pressure of Steam: lbs. per Square Inch.	Amount of Draught in Boiler Flue: mm. of Water.	Colour of Flame as seen from End of Boiler Flues.	CO_2 in Producer Gas.	Temperature at End of Boiler: Deg. Cent.	CO_2 in Escaping Gases.	Temperature of Waste Gases to Chimney: Deg. Cent.	Temperature of Feed Water: Deg. Cent.	Total Water used, in lbs.	Water used per Hour.	Total Coal used, in lbs.	Coal used per Hour.	Lbs. Water Evaporated per lb. Coal, Feed Water 40° C. Steam 60 lbs. per Square Inch.	Calculated Evaporation, Water at 100° C., or Steam at Atmospheric Pressure.
			Ft. In.				% cent.		% cent.								
August 12	11	Main coal	6 0	50	6	Dull red	—	—	—	—	40	35,973	3,270	4,032	366·5	8·92	10·56
,, 13	1 4	,,	5 6	50	6 (about ¼ inch.)	,,	5·90	482	17·00	260	40 (108° to 109° F.)	47,021	3,358	5,488	392·0	8·50	11·00
,, 14	14	,,	5 0	50	6	,,	4·86	(900° F.)	15·95	(500° F.)	40	46,636	3,331	4,928	352·0	9·46	11·20
,, 15	14	B ,,	6 0	50	6	,,	6·00		14·06		40	44,580	3,184	4,928	352·0	9·00	10·60

The following is extracted from the Report of a trial made by Mr D. K. Clark in 1886, with four Cornish boilers and two gas producers.

"The boilers were each 5½ feet in diameter, with a 3-feet furnace tube, and 21 feet long, having eight Galloway tubes in each.

"The producers stood side by side in an open yard adjacent to the boiler-house. Each producer was cylindrical, 8 feet in diameter, 9 feet high, of firebrick cased in plate iron. The gas was conducted by an underground conduit to the boilers, where the supply of gas to each boiler was regulated by means of a valve. The gas was delivered through the doorway, together with air, into the furnace tube, where combustion took place.

"The four steam boilers were set in a row. No. 1 boiler was separated from the rest, and was devoted to the generation of steam for supplying the blast injector attached to each producer. The three remaining boilers were connected for the supply of steam to the factory.

"The quantity of steam consumed specifically for the creation of blast was thus measureable in terms of the feed water consumed by No. 1, whilst the quantity of steam generated by Nos. 2, 3, and 4, similarly could be measured.

"The coal consumed in the producers was cobbles from Wyken Colliery, broken up by hand, and charged into each hopper four times per hour.

"For the purpose of the test, which lasted five hours, the coal supplied to the producers was weighed, and the feed water supplied to No. 1 and to Nos. 2, 3, and 4 together, was measured separately. The level of the water in the boilers was maintained at the same height at the end of the trial as at the commencement.

"The leading results of the test are given in the following table, and for the sake of comparison the results of a six days' test which had previously been made with hand firing are prefixed. In this case, the fire grates were 4 feet 8 inches long, presenting an area of 14 square feet for each boiler.

HAND FIRING *versus* GAS FIRING.

Date of trial	Sept.—Oct., 1886.	Nov. 19, 1886.
Kind of trial	Hand Firing.	Gas Firing.
Kind of boilers	Cornish.	Cornish.
Number of boilers in steam	4	4
,, ,, full steam	4	3
Duration of trial	142 hours.	5 hours.
Description of coal	Wyken cobbles.	Wyken cobbles.
Average pressure of steam per square inch	57·25 lbs.	55 lbs.
Average temperature of the atmosphere	—	52° F.
	Tons. Cwts. Qrs. Lbs.	T. C. Q. L.
Coal consumed	41 6 1 11	1 14 2 15
,, ,, per boiler in full steam	10 6 2 10	0 11 2 5
,, ,, ,, ,, per hour	163 lbs.	258·6 lbs.
,, ,, per square foot of fire grate	11·64 feet.	
Temperature of feed water	54°	57½°
Water evaporated by boilers in full steam	8,476 c. feet.	374·82 c. feet.
,, ,, ,, ,, per hour	59·69 ,,	74·80 ,,
,, ,, per boiler in full steam	2,119 ,,	124·67 ,,
,, ,, ,, ,, per hour	14·93 ,,	24·94 ,,
,, ,, by No. 1 boiler (producer)	—	33·80 ,,
,, ,, ,, ,, per hour	—	6·76 ,,
Total water evaporated by four boilers	—	407·82 ,,
,, ,, per hour	—	81·56 ,,
Water evaporated per lb. of coal	5·71 lbs.	6·56 lbs.
Net ,, ,, by three boilers in full steam, exclusive of steam for producer	—	6·02 lbs. net.
Ditto ditto from and at 212°	6·79 lbs.	7·16 ,,

"The following data may be re-stated for comparison :—

	Hand Firing.	Gas Firing.
Coal consumed per boiler in full steam per hour	163 lbs.	258·6 lbs.
Water evaporated per boiler in full steam per hour	14·93 c. feet.	24·94 c. feet.
Water per lbs. of coal from and at 212° F.	6·79 lbs.	7·16 lbs. net.

"It is shown that the boilers in full steam did two-thirds more evaporative duty by gas firing than by hand firing, and with 5½ per cent. more evaporative efficiency, after allowance made for steam consumed in blowing the producers. It is also shown that the weight of steam consumed by the producer is $\frac{33{\cdot}80 \times 100}{407{\cdot}82}$ = 8·29 per cent. of total quantity generated in the four boilers.

"The total evaporative efficiency of the boilers with gas firing, if no deductions be made for the demands of the producers, is expressed by 6·56 lbs. of water per lb. of coal, or an equivalent of 7·81 lbs. from and at 212 deg., which is 7·81 − 6·79 = ·98 lb.,

or 14·4 per cent. more efficiency than was obtained by hand firing. This is an expression of the absolute difference of efficiency in favour of gas firing. The practical difference after making the needful allowance is, as above stated, 5½ per cent.

"Smoke was frequently visible at the top of the chimney during the trial with gas firing, ranging from No. 1 to 7 of the smoke abatement scale.

"This was evidence of deficiency of air, or of imperfect mixture of the air and the gas. In fact the furnace doors of Nos. 2, 3, and 4 boilers were 2½ inches open for the whole time to make up the proper supply of air. I should add that the attendant on the gas firing complained that he had to force the fire in order to keep up the pressure of steam. He called attention to the smallness of the back flue of the boilers.

"At intervals, of course, no smoke was visible with gas firing, and there is no reason why, under fitting conditions, gas firing should not be conducted entirely without smoke.

"Although the results of the comparative trials prove so far as they go in favour of gas firing against hand firing, yet they are not quite conclusive, as the experimental boilers were evidently not worked under the most fitting conditions for either hand firing or gas firing. Considerably more than 14·93 cubic feet of water should have been evaporated per hour in each boiler, and a greater evaporative efficiency than 5·71 lbs. of water per lb. of coal should have been shown. At the same time it is probable that with fitting conditions the gas firing also would have exhibited greater efficiency.

"On the whole, I am disposed to accept the percentage of advantage in favour of gas firing ascertained by the comparative trials, namely, an absolute difference of 14·4 per cent., or a net difference of 5½ per cent. in favour of the gas firing.

"This deduction fully harmonizes with the best result of Mr J. H. Darby's experiments at Plas Power Colliery, which shows a greater absolute efficiency of 9·85 per cent. in favour of gas firing, or a net efficiency of 4 per cent in its favour.

"Looking to the evidence of greater evaporative efficiency and a greater rate of production of steam, it appears that the system of gas firing is worthy of a more extended trial.

"In estimating the pecuniary saving by its adoption, the cost of maintenance of the two producers may be taken at 10 per cent. per year on the first cost = £300. Against this, with interest on the capital, is to be set off the saving in cost of fuel and its attendance."

In the trials referred to previously as having been conducted in America by Mr Dixon, under Messrs Gadsden & Co., there were eight boilers, each 24 feet 6 inches long by 3 feet 10 inches diameter, with two return flues each 17½ inches diameter, all connected by steam and feed drums, over one continuous grate 41 feet long by 6 feet broad, with eight firing doors. The flame, after passing under the boilers, returns through the flues, a brushing in front connecting them with stacks in pairs. The heating surface by American formula amounted to 3,300 square feet, and the effective surface, according to rules in Box's Treatise on Heat, about 2,100 feet.

The consumption of coal by hand firing was about 5,400 lbs. per hour, with an evaporation of about 25,500 lbs. of water per hour, or less than 4¾ lbs. per lb. of coal, and about 12 lbs. per square foot of effective heating surface.

Four producers were first applied, burning between 1,600 and 1,700 lbs. of coal per hour, the gas and air being admitted to the boilers by iron burners as shown in Fig. 31. With the four producers clean and working well the evaporation amounted to 14,500 to 15,000 lbs. per hour, or say 8½ lbs. of water per lb. of coal, or 7 lbs. for each square foot of effective heating surface.

Three more producers were added, first with the same combustion arrangements, and afterwards with those shown in Figs. 30 and 31.

The plans illustrated in Figs. 32, 33, and 34, and finally in Figs. 35 and 36, have also been tried. Some slight modifications of these, especially of the last, were also tried, but without affecting the result materially, so that, with the seven producers working full, the greatest evaporation obtained was 20,000 lbs. of water per hour. An eighth producer was finally added, but it was found that there was no additional evaporation

by the combustion of the additional quantity of gas. In fact, six producers gave as large a result as seven, whilst more steam per lb. of fuel was obtained when working four producers.

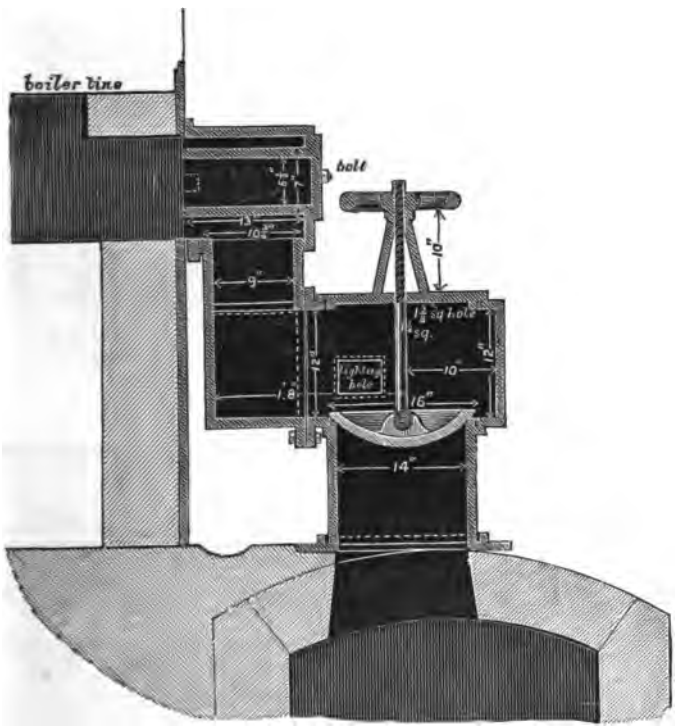


FIG. 31.

Mr Dixon remarked as follows on these results as compared with those given in Mr Darby's report:—"Darby's Report confirms the conclusions I have drawn. Observe that in his trial No. 1, 750 lbs. of coal per hour were consumed, or nearly 2 lbs. for every square foot of effective heating surface, and only 5·8 lbs. of water per lb. of coal. In trial No. 3, only 438 lbs. of coal were

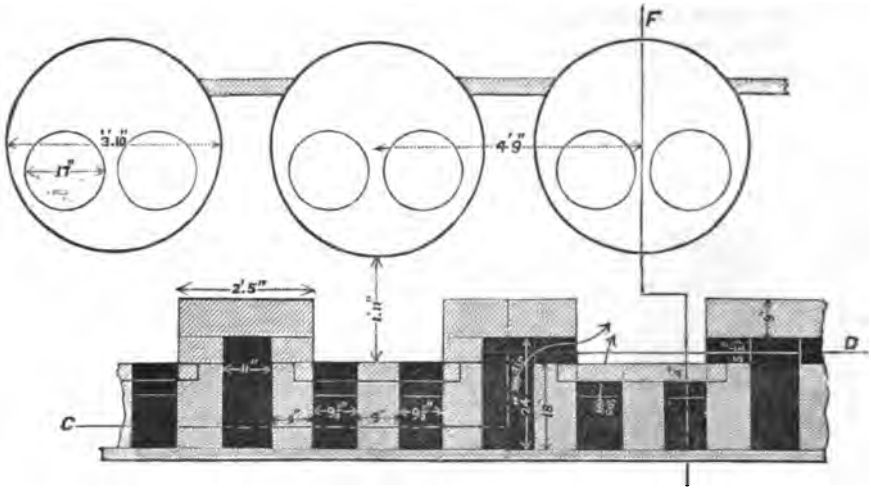


FIG. 32.

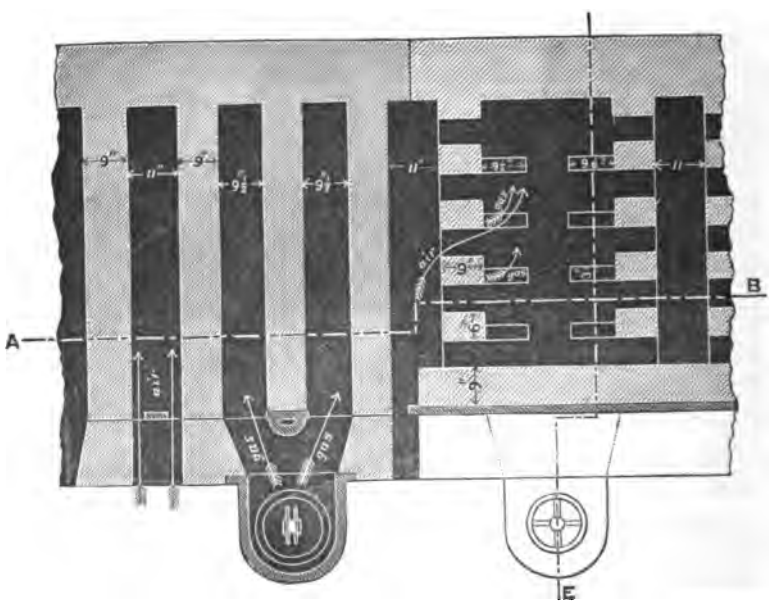


FIG 33.

consumed per hour, less than 1 lb. for each square foot of heating

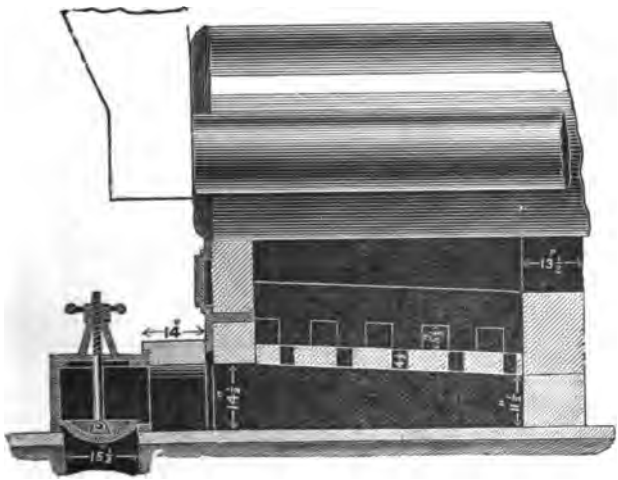


FIG. 34.

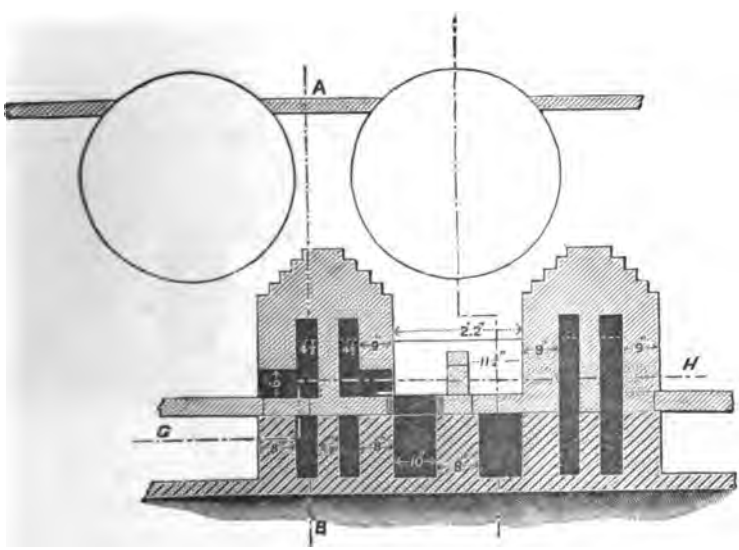


FIG. 35.

surface, and 8·6 lbs. of water per lb. of coal, which is very fair.

In the first instance, at considerable expense of gas, he succeeded in getting each effective square foot to evaporate nearly 10 lbs.

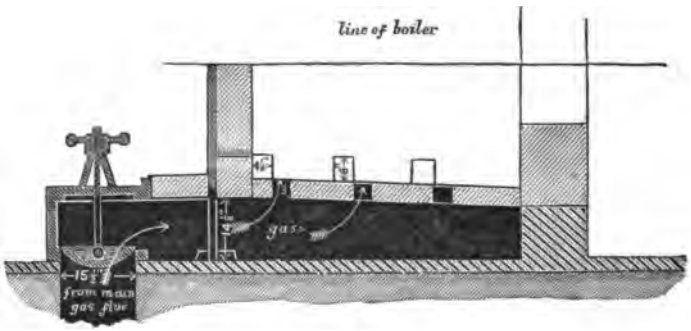


FIG. 36.

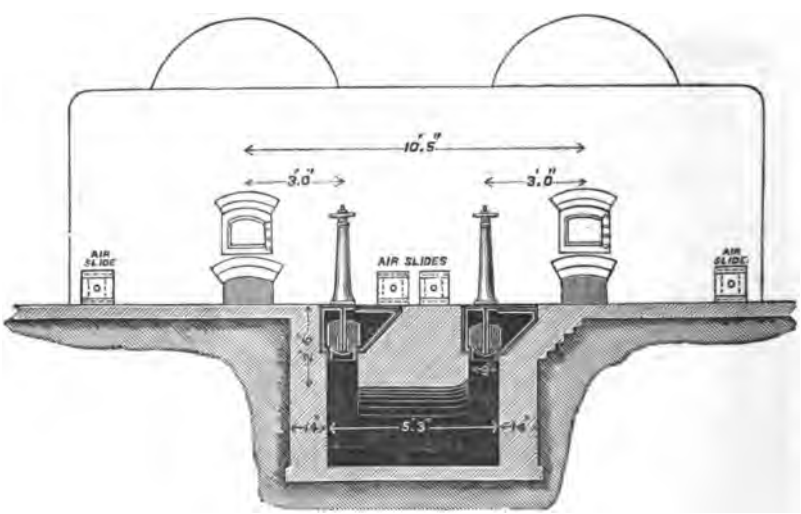


FIG. 37.

per hour. In the latter the evaporation was 8½ lbs. per square foot per hour, which is more than a boiler should be called upon

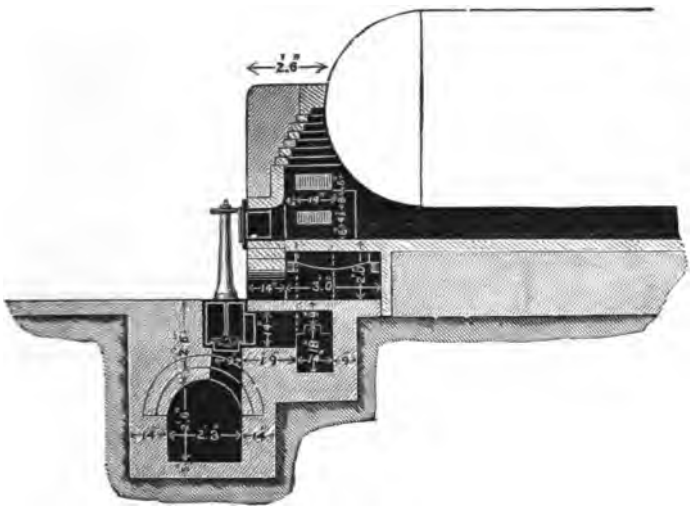


FIG. 38.

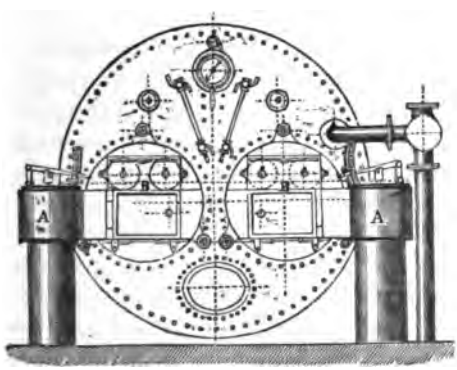


FIG. 39.

to do. Had the consumption of fuel been reduced to ½ lb. per square foot, or 220 lbs. per hour, the evaporation would probably have been 10 lbs. of water per lb. of fuel, or 5 lbs. per square foot of surface per hour, which is the economical point.

"In our trials, our first, with four producers, was nearly equal

to Darby's third and best; whilst our worst, as far as economy of fuel was concerned, with eight producers was but little under his first. Our not being able to properly control chimney draught would account for the difference in both cases."

In order to illustrate the application of gas to different forms of boilers, Figs. 37 and 38 are added, showing the method of firing egg-ended boilers, and also Fig. 39, which shews an ordinary method of firing Lancashire boilers.

The only other plan to which we shall here refer, on account of its great interest, is that of the gas-fired boilers at the Engineering Works of Messrs David Rowan & Son in Glasgow. At first one boiler was tested with gas firing against a similar boiler alongside fired by hand, and comparative results were thus obtained. Both were subsequently fired by gas, and continue to be worked on that system. The boilers are constructed of steel, each 10 feet 6 inches long by 8 feet 6 inches diameter, and contain eighty-two tubes of 4 inches external diameter, extending from end to end of the boilers. The tube surface is 901 square feet, and the area of shell which is exposed to heat is 133 square feet, the total heating surface being thus 1034 square feet. With hand-firing, there were 33 feet of grate area, whilst with the producer there are 15 square feet; so that formerly the ratio of heating surface to grate surface was 31 to 1, whilst with gas-firing it is 69 to 1.

Originally the flues were arranged in the hand-fired boiler so that the flame and hot gases returned from the back of the boiler to the front directly through the tubes, and then were conducted along the sides to the chimney-flue at the back. As thus arranged, a week's trial gave 5·651 lbs. of water per lb. of coal as the evaporative rate. The course of the hot gases was altered by causing them first to return to the boiler front by the side flues, and finally to reach the chimney-flue by the small tubes, and the result of this alteration was to raise the evaporative rate to 7 lbs. of water per lb. of coal. It was found that in the old

arrangement the tubes extinguished the flame, and that a large quantity of unconsumed gas escaped to the chimney, which, with the altered arrangement, could be burned in the side flues.

By means of experiments made with boiler tubes placed over a jet of crude gas from a Siemens producer, Mr W. Anderson found that 6 feet was the maximum length which a boiler tube of 3 inches diameter should have if combustion were intended to go on in it. It is probable that Mr Anderson used vertical tubes, which might be expected to give a better result than the same tubes in a horizontal position. In Messrs Rowans' boiler the tubes were horizontal, so that in spite of their slightly larger diameter, the extinguishing effect may have occurred within Mr Anderson's limit of length.

In the gas-firing arrangement, gas is generated in a rectangular producer, 5 feet by 4 feet, the grate surface being 15 square feet, and the coal being kept at a depth of 2 feet to 2 feet 6 inches on the bars.

Air is supplied from a Root's Blower to the ash-pit of the producer, which is closed by an air-tight door, and the gas is led from the producer over an inverted arch to the under side of the boiler, where it meets a supply of heated air. Ignition here takes place, and the flame passes along under the boiler, returns along the side flues, and thence through the tubes to the chimney-flue. In order to heat the air for combustion, there are twelve rows of fire-brick tubes, 3 inches internal diameter, placed in the bottom of the boiler setting and heated there by radiation from the combustion chamber, and the air from the blower is directed through these—first through five, and then through seven—to the combustion space, where it meets the hot gas from the producer.

The opening for escape of the gas from the producer to the combustion chamber is about 48 inches by 3 inches, or 144 square inches, which, with 15 square feet of grate surface, is nearly 10 square inches of opening for every square foot of grate. This, Mr James Rowan, who described this plan to the Graduate section of the Institution of Engineers in Scotland, considered to be a good proportion, as the gas was not restricted in its escape

by the opening being too small; and, on the other hand, the producer and chamber were not turned into an ordinary air-furnace by the opening being too large.

The surface of the arch occasionally collects a deposit of tarry soot, which is, however, easily cleaned off; and, except just at the period of charging fresh fuel, the process is entirely smokeless. The charging is carried out by hand through the firing-door shown in the illustrations, but there is no reason why a hopper, with bell cone or similar arrangement, should not be used. This has the advantage of preventing the ingress of cold air to the producer, or of allowing the escape of much gas.

The evaporative results obtained with this arrangement were, in one trial, 9½ lbs. of water evaporated per lb. of coal consumed; and in another, which extended over three days, using a good quality of splint coal, 10·8 lbs. of water were evaporated per lb. of coal burned. The latter trial was made simultaneously with the trial of hand-firing referred to, when 7 lbs. of water were evaporated per lb. of coal, the same quality of coal having been used for both boilers. It thus appears that the gas-fired boiler evaporated 51 per cent. more water per unit of coal burned than the hand-fired boiler.

The following are the total quantities of coal used and water evaporated by the gas-fired boiler in the first trial referred to, which lasted from 1 P.M. on 11th February, 1882, to the same hour on the 18th of that month. The quality of the coal used was ordinary "triping" or unriddled coal, from the Hamilton coal field. During the trial the engine was working for 58 hours

Water evaporated, - - - -	185,123 lbs.
Coal burned, - - - - -	19,488 lbs.

= 9·499 lbs. of water evaporated per lb. of coal burned.

This arrangement of Messrs Rowans' is shown in Figs. 40 to 42, Fig. 40 being a plan in section with the boiler removed, Fig. 41 a longitudinal elevation in section, and Fig. 42 a cross-section.

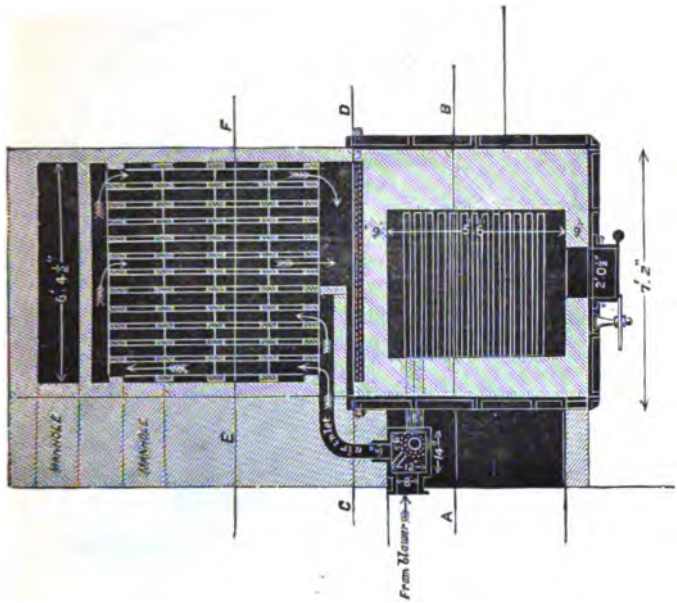

F
E
D
C
B
A
6' 4½"
MANHOLE
MANHOLE
9"
5' 6"
9"
2' 0½"
7' 2"
14"
From Blower

FIG. 40.

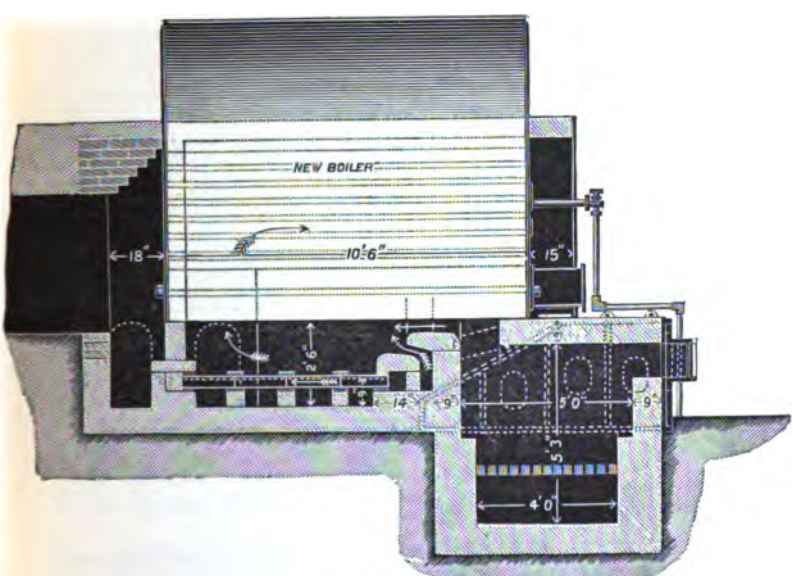

NEW BOILER
18"
10' 6"
15"
2' 6"
14"
9"
5' 0"
9"
5' 3"
4' 0"

FIG. 41.

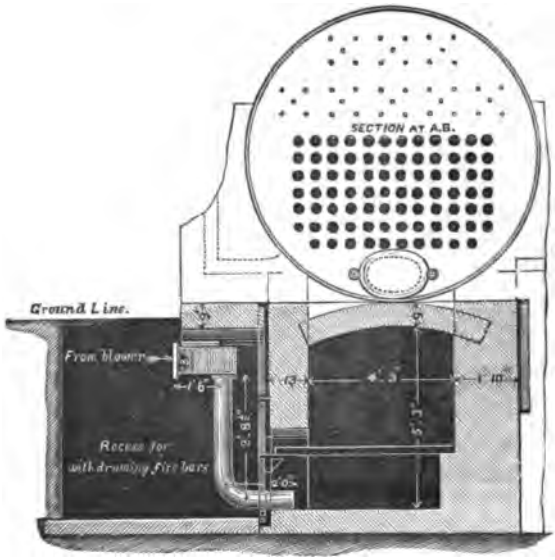

SECTION AT A.B.
Ground Line.
From blower
1' 6"
R
4' 3"
1' 10"
2' 9½"
5' 3"
Recess for
with drawing fire bars
20°

FIG. 42.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

HALL OF THE INSTITUTE, HAMILTON,

11th July, 1889.

JAS. S. DIXON, Esq., ex-President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary and confirmed.

The following were elected by ballot as Ordinary Members :—

J. H. JOHNSON, St. Helens Colliery, Workington.
GEORGE SCOULAR, Parkside Mining Co., Whitehaven.
ANDREW PEARSON, Priestfield Terrace, High Blantyre.
ALEX. SIMPSON, Knockterra Colliery, Cumnock.
W. M. MILLAR, 34 St. Andrew Square, Edinburgh.

The following discussion then took place :—

DISCUSSION OF MR F. J. ROWAN'S PAPER ON "GAS-FIRED BOILERS."

MR ROWAN, in answer to the Chairman's question, as to whether he had anything to add, said he had only to thank the editing committee for having illustrated the paper so thoroughly.

The CHAIRMAN said, in regard to the subject of gas-firing, he was rather interested in it two or three years ago, and was anxious to learn whether the small gum made at their riddling machines could be utilized in gas producers. He sent samples to the Glenfield Works, Kilmarnock, where they had Wilson's producers at work, but the small particles clogged up the producer, so that the steam or air would not penetrate it, and Mr Kennedy, the managing partner, reported that it was of no use. His object was to get the best plan of utilizing this gum, and since then he had tried watering it thoroughly, which had met the purpose to some extent; but, if Mr Rowan could tell whether such material could be utilized in a producer it might be an element for the members to consider, as it was rather difficult to deal with in ordinary boilers.

Mr ROWAN said, at pp. 83-86, there were plans illustrated by which mud from coal-washing machines had been successfully used for firing boilers in Germany. They would find a statement on page 83 to that effect. He believed the reason was that the depth of fuel in those fires was much less than in the ordinary gas producers which they had at Glenfield, and also that grate bars were used instead of a solid hearth.

The discussion was adjourned.

The following paper on a "Patent Petroleum or Naphtha Engine" was then read by Mr T. H. Mottram:

PATENT PETROLEUM OR NAPHTHA ENGINE.

By Thomas H. Mottram.

I have been asked by the President to give a short account of a patent petroleum engine, recently erected at No. 5 Rosehall Pit, belonging to Messrs Robert Addie & Sons, Coatbridge.

A few days ago I had an opportunity of seeing this engine working an underground pump. Previous to the erection of the engine, the pump, which is one of Warner's treble gin pumps, was worked alternately by two horses (14½ hands), which were kept entirely for the purpose.

It was a matter of some difficulty to get the work performed by these animals, for the constant strain of a side pull, while traversing the ring, produced sores on their necks, and, in consequence, changing was occasionally necessary; and I am informed by the manager, Mr John Smith, that it was no uncommon thing for a fresh horse to break out a tooth or two of the horizontal wheel of the pump before getting used to the work.

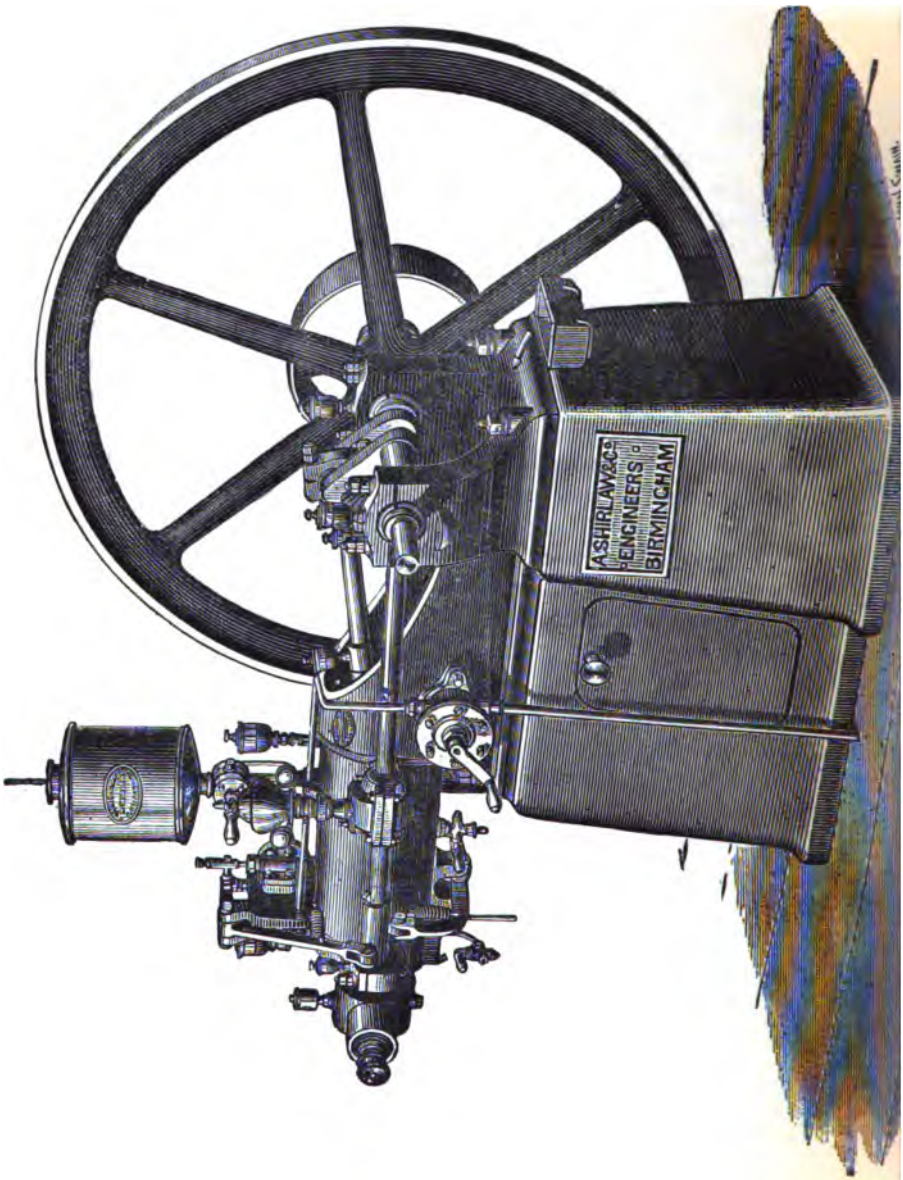
The difficulties described, together with the probability of requiring further additional work performed, led the manager to look out for some other and more adequate means to drive the pump.

The pump is situated 350 yards from the pit bottom, at the side of a dook road dipping 1 in 6, and at a distance of about 15 feet from the pump, connected by a driving belt, Messrs Addie have erected one of Spiel's patent petroleum engines, which is now driving the pump, and so doing the work formerly done by the horses.

The engine, which occupies a small house about 9 feet square, has a cylinder 6 inches diameter, with a stroke of 12 inches; driving pulley, 20 inches diameter, the pinion wheel on the shaft of which drives the pump. The normal speed of the engine is about 210 revolutions per minute. Fig. 1 is a general elevation.

Naphtha is the fuel, and the engine consumes 3 gallons per working day of from 7 to 8 hours. The naphtha is taken down the pit each day in tin bottles, which contain only what is required for the day's work, and are emptied into the reservoir on the top of the engine, shewn in the figure, and the supply,

FIG. 1.



which is automatically controlled, is then conveyed through a pipe to the cylinder.

An oil plunger measures in a definite quantity of naphtha; a supply of air is also admitted through a valve for the purpose, and the mixture of air and oil, thus measured, falls through a tube, in which it becomes mixed before entering the cylinder in the form of a spray.

At the back end of the cylinder, facing the discharge pipe, there is an igniting or firing valve at which is placed a small spirit lamp, and as the measured sprays of oil and air are admitted into the cylinder, a succession of explosions occur and act upon the piston, just as the igniting valve opens and shuts.

The work performed by this engine is as follows:—The pump has three 3½-inch plungers, 9-inch stroke; and every 210 revolutions per minute of the engine give 20 strokes of each plunger, equal to 107 cwt. per hour, or about 40 tons of water per day of 7½ hours.

This water is forced up to the top of the dook, a vertical height of 69 feet, the pressure on the plungers being about 30 lbs. to the square inch.

In addition to this, the engine also drives a rope pump, 260 yards further down the dook road, the bucket of which is 5½ inches diameter, 8 inch stroke, with a speed of 12 strokes per minute, giving 46½ cwt. per hour, or 17¼ tons per day of 7½ hours. This water is raised a vertical height of 53 feet, and delivered into the lodgment at the larger pump, the pressure on the bucket being about 23 lbs. to the square inch.

The weekly cost of working the engine, as given by Mr Smith, is as under:—

Naphtha—7 days, @ 3 gals. per day, = 21 @ 7½d,	£0	13	2
Methylated Spirit, ...	0	0	4
Price's Patent Lubricating Oil, ¼ gal. @ 4s, ...	0	1	0
Ordinary Machinery Oil, ½ gal. @ 2s 4d, ...	0	1	2
	£0	15	8

The man who looks after this pump also attends to haulage arrangements; he is paid 2s 8d per day, and if we charge one-half of his wages to the pump, viz., 9s 4d per week, the weekly cost is brought up to 25s—not a large sum by any means.

For comparison, the weekly cost of horses was as follows :—

Horses' keep, &c.—2 @ 10s 6d, ...	£1	1	0
Half cost of driver—7 days @ 2s 2d, ...	0	7	7
	£1	8	7

The starting of the engine seems to be a very easy matter indeed, all that is required, if charged with naphtha, being simply to light a small lamp at the igniting valve and to turn the fly-wheel, when the engine will start off, and it apparently requires little or no attention afterwards.

In order to keep the cylinder cool, it is fitted with a jacket, in which water is kept in circulation from a tank for the purpose.

The exhaust from the engine is conveyed through a stopping into the return airway, only a few feet distant, where it is mixed with some 15,000 cubic feet of air per minute, and passes direct to the upcast shaft.

The engine has been at work now about 10 weeks, and at the time of my visit seemed to be working well, and the manager is thoroughly satisfied with it.

In non-fiery mines, where small quantities of water require to be dealt with, which would not warrant a large outlay, this engine seems to be an admirable arrangement, provided ordinary care be exercised, and where also the exhaust can be conveniently conveyed, as in the present case, direct to the upcast shaft, without passing through the working places.

DISCUSSION.

The CHAIRMAN asked if the fumes were very noxious.

Mr MOTTRAM said there was a decided smell from the exhaust, but, inasmuch as there was a large volume of air passing, after twenty or thirty yards' distance very little smell was discernible. This would otherwise be an objection, but here it was close to the upcast, and it very much depended on the amount of air passing. If an objectionable quality of naphtha were used, the exhaust was proportionately bad.

The discussion was adjourned.

The following paper on "Air Vessels," by Mr Allan Andrews, was then read by the Secretary :—

AIR VESSELS.

By Allan Andrews.

The important part played by air vessels in connection with pumping water from deep mines is a matter well worth the attention of every one connected either with the making of pumps for such purposes or superintending them after they are set to work. And to me it seems remarkable that hitherto so little consideration has been given to what, in my opinion, is a very important adjunct to a great majority of the pumps which work on the forcing principle, but particularly those worked by a crank —the motive power being an engine with a fly-wheel. I was, therefore, much pleased to see that the matter was taken up at a recent meeting of the Mining Institute, when a paper on the subject was read by Mr Dugald Baird. In this paper, and the discussion which followed, much valuable information was elicited —tempered, however, with a modicum of what I may call popular error. With your leave, therefore, I would respectfully submit for the consideration of those whom it may concern a few reflections on this important subject—the outcome of a lengthened experience of pumps of all kinds—but with particular reference to heavy pumps and deep mines. There are three requisites which I consider essential to the proper working of an air vessel: —(1) Its dimensions; (2) Its supply of air; (3) Its position. I will take these in their order:—

(1.) In my opinion, a great many people fall into the error of having the air vessel too small. Four times the capacity of a stroke of the plunger is generally considered a proper size. Assuming, then, that an air vessel of that size has been connected to a plunger pump forcing 100 fathoms, and that the air vessel is placed in the most advantageous position, I will consider and endeavour to explain what effect such an air vessel will have on the working of the pumps. Let it be assumed that the rising main, and consequently the air vessel, are empty, except that they are full of air at the pressure of the atmosphere, and the pumps are set to work. The statical pressure, be it observed, due to 100 fathoms is about 260lbs. to the square inch, which is fully 17 atmospheres. It is evident that, as the water ascends in the

rising main, the air in the air vessel will get compressed more and more till, when the water reaches the landing-box, the air will be compressed into the seventeenth part of its original bulk, and, with the exception of that seventeenth part, the air vessel will be filled with water. This would be the state of matters, provided the water, under such a high pressure, absorbed none of the air. But we know that water absorbs air in large quantity under high pressure, so the probability is that not more than a twentieth part of the air vessel will be filled with air. But, as the air vessel was only four times the capacity of the plunger to begin with, the part now filled with air will only be one-fifth the capacity of the plunger, and before even the half of that fifth part can make room to hold water, it must be compressed still more. Although compressed into the half of its bulk (which means the pressure against the ram raised from 260lbs. to 520lbs. on the square inch), even then it would hold only one-tenth the capacity of the plunger, and the other nine-tenths must go up the column, or something must give way. It is quite evident that an air vessel under such circumstances is a delusion and a snare. No wonder that a great many people, who think they understand the working of pumps, have come to the conclusion that air vessels are of no use. The truth is that air vessels are generally quite inadequate in point of size. An air vessel cannot be too large. I would say that ten times the capacity of the plunger would not be excessive, and it cannot be too highly charged with air. Suppose it were ten times the capacity of the plunger, and two-thirds of it were filled with air at the statical pressure due to 100 fathoms, that two-thirds would be about seven times the capacity of the plunger. The air vessel, in such a condition, could hold a full stroke of the pump, although the water in the column never moved, and the pressure would be increased only from 260 to 297lbs. But the water in the column not moving is such an abnormal state of things that it could hardly occur, and the actual increase of pressure, in all probability, would never be 10lbs. in excess of the statical pressure.

(2.) *Supply of Air.*—A great many air vessels are condemned as being practically useless, and even consigned to the melting-pot

as being otherwise of no use, through no fault of the air vessel, but from want of knowledge or inattention on the part of the person taking charge of the pumps.

It is the common belief, I have no doubt, that an air vessel, once filled with air at the atmospheric pressure, will remain permanently so, unless there be a flaw in the vessel itself. Most people come to know after a while that the air vessel is not doing its duty as it did at one time, and they very properly account for this that the air has somehow escaped from the air vessel, but very improperly lay the blame on the iron-founder for having made an imperfect casting, under the erroneous belief that there is no escape for the air except through the metal of the casting. I will endeavour to explain how the air escapes, even although the air vessel be quite impervious.

It is well known that water, under all pressures, absorbs and retains more or less air, and that, the higher the pressure, the more air is absorbed. A very instructive illustration that water, under the pressure of the atmosphere, contains air is afforded by placing a quantity of water under the receiver of an ordinary air pump. The operator has no sooner begun to work the pump than air bubbles are seen to rise out of the water. A more familiar example can be seen any day by drawing the cork of a soda-water bottle. Soda water, as is well known, is produced by forcing carbonic acid gas into a receiver partly filled with pure water, until the pressure is perhaps as high as 100lbs. to the square inch. The water absorbs the gas in large quantity, and is consequently very highly charged. This highly charged water is then bottled and securely corked. So long as the cork remains in position, the water is perfectly quiescent, but the moment the cork is withdrawn, and the pressure thereby removed from the surface of the water, the gas immediately escapes furiously, and generally with such impetuosity as to carry the water along with it. Apply this principle, then, to the water inside an air vessel.

As has been already explained, the air above the surface of the water in the air vessel is compressed to upwards of seventeen atmospheres, and, as has also been explained, water under one atmosphere contains a certain amount of air, and, as in the case of the soda-water bottle, we know that water under a higher

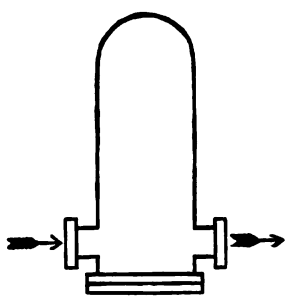
pressure, contains more air. I am safe to assume that the water in an air vessel, under a pressure of seventeen atmospheres, will contain seventeen times as much air as water under one atmosphere. Now, if the air vessel is serving any purpose, there must be a constant ebbing and flowing of the water within it. But the water which flows out is charged with seventeen times as much air as the water which goes in—the latter being merely the water as it is drawn from the lodgment. Hence, it is only a question of time—and, in all probability, a very short time too—when no air whatever will be left in the air vessel, and an air vessel full of solid water is just the same as if there were no air vessel at all.

To render an air vessel of any use it is absolutely necessary that there should be a constant supply of air going into it. The quantity, however, is not great. Still there must be as much going in as compensate for what is going out, or the inevitable result will follow; and, as a small quantity escapes with every variation of pressure in the air vessel—which, when properly performing its duty, is practically with every stroke of the pump—so, in like manner, a corresponding quantity should be admitted with every stroke of the pump. A small pet cock on the suction pipe of the pump is by far the simplest, cheapest, and most easily managed method of charging the air vessel with air, and is as efficient as the most expensive apparatus, such as an air pump, &c. When it has been ascertained from the rough working of the pump that the air vessel has got emptied of air, a common method of recharging it is to empty the column. This will, no doubt, fill the air vessel with air, but only at the pressure of the atmosphere. But it is a round about way of doing it, and besides has the disadvantage that the water run off has to be pumped over again. Another method often resorted to is to slack a joint on the suction pipe. This method will no doubt answer the purpose, but it is clumsy, attended with trouble, and will soon result in spoiling joints.

It has often been remarked that a little air admitted into the suction pipe causes the pump to work more smoothly, and this is no doubt true. The quantity, however, must be only as much as will amalgamate with the water in a state of froth. When the water is so charged with a little air it is somewhat elastic; hence

the smooth working. Should the air, however, be in excess of what will amalgamate for the time being with the water, instead of doing good it will do harm ; and, in any case, whatever portion of air is admitted is just so much less water pumped. Great care is consequently necessary in regulating the admission of air into the suction pipe. A safe rule would be to admit no more than would just keep the air vessel properly charged.

(3.) *Position of Air Vessel.*—For a vertical pipe, the air vessel with an internal pipe placed on the rising main is perhaps as good as any, but there should be no cap near the bottom of the internal pipe. The cap can do nothing but harm. Anything it can possibly do is to prevent the water getting too ready access to the rising main. The rising main is the ultimate destination of the water ; and if, in its travel, it can get easier into the rising main than up into the upper portion of the air vessel, why prevent it ?



For a horizontal discharge pipe the air vessel is often connected to a branch on the upper side of the pipe. This is bad, very bad. The tendency of all heavy bodies in motion is to continue their course in the same straight line. Before the water can get into an air vessel so placed it must turn a sharp right angle, and before it can get out it must turn another similar right angle. It is not difficult to understand that with a straight road for the water to pass along the pipe, and having already acquired an impetus in that direction, there can be very little intercourse between the pipe and the air-vessel.

In my opinion the proper way to place an air vessel on a horizontal pipe would be as per sketch. The entrance and exit of the water being by separate branches, there are no conflicting currents; and the air vessel being large in comparison to the branches, there is ample time for the water to part with the air that is incorporated with it, and so keep the air vessel always properly charged. Air vessels should always be fitted with a glass gauge to show the position of the water, and in addition fitted with a pressure gauge, which would show what amount of air in the vessel produced the least variation in the pressure, —the minimum variation being the maximum benefit of which the air vessel is capable. The most favourable condition will no doubt be found to be when the vessel is well filled with air.

The idea of placing an air vessel half way up the shaft, as has been proposed—and, I understand, has actually been put in practice—seems to me preposterous in the extreme. If an air vessel already fitted to the pump is found to be too small, by all means supply a second one, but let it, as well as the first, be placed as near the pump as possible. The purpose of an air vessel is to counteract or qualify the *vis inertia* of the water. That being its function, it is evident that it cannot be too near the pump. *Vis inertia* has no relation to pressure. It relates only to the weight of the body and the speed it is going at if it has to be stopped, or the speed it must attain if at rest. Hence the less weight of water that has to be moved before it meets the air cushion—that is, the air vessel—the better. If an air vessel were placed half way up the shaft, the half of the weight of water must be moved before that air vessel could come into action; so that, at best, it could only do half work. I don't approve of placing an appliance of any kind where it will do only half work, more particularly when it is just as easy to place it where it will do full work, that is, place the air vessel as near the pump as it can be got. Cornish, and other pumping engines of the direct-acting class, where the weight of the rods forces up the water, have no need for an air vessel. The rods, if properly proportioned, cannot force up the water beyond the proper speed; and even if the rods are too heavy, and in consequence would incline to descend too rapidly,

the speed must be restrained by a back balance, or by throttling the exhaust.

An air vessel on the suction is only necessary when the suction is of great length, or when there is a considerable tail lift, or a quick going pump, such as a feed pump on a winding engine. In ordinary circumstances pumps in a pit have no need for an air vessel on the suction.

In my opinion the air vessel is of such importance for a heavy pumping on the geared principle, or wherever the steam forces the water, and such a slight inattention may have such serious results, that it should be an instruction to the oversman, when going his rounds, to take note of the position of the air in the air vessel, and record the same in a book kept for the purpose.

DISCUSSION.

The CHAIRMAN, in adjourning the discussion, spoke of the excellence of the paper, and said he was sure it would be so from the experience Mr Andrews had had for a life-time in work of this kind.

COMMITTEE'S REPORT ON COAL CLEANING.

The SECRETARY said the report had not yet been completed. It had been in the hands of three different parties who visited three different districts of England. They had got the report in draft, but it had not been considered by the committee as a whole, and he was not in a position to read it. The object of bringing the subject forward was to have it in the hands of the printer and lithographer as soon as possible. The plans were numerous, and they expected when the report was printed it would be very satisfactory and complete. It would cer-

tainly be the most expensive report they had ever had, and he thought it would also prove a very useful one. It was not likely that it could be printed in the next issue of the Transactions.

The CHAIRMAN said he thought it was not desirable that they should hurry preparation of the report too much. If the report could be published, after being thoroughly digested, in time for the second meeting, it was all very well, but if there was any further information that could be got, he did not think it desirable to push it on too quickly. It was a report that would contain a great deal of information. There had been an Editing Committee appointed to go over the sub-reports, because in some cases there were two descriptions of the same machine, and they would be able to focus the various matters. He thought they should authorise them, if they found it necessary, to delay the report for a month. It would be better to do that than to have it in any way incomplete.

The SECRETARY said that the Council really expected that the members of the Institute would have met the committee in this matter, and have furnished them with particulars of coal-cleaning appliances which they themselves found useful. He was sorry to say he had not got any response to the circular.

The CHAIRMAN said he would urge in furtherance of what Mr Barrowman had said that this should still be done. It was at that he hinted when speaking of delay. If the members would send in a description of the appliances used by themselves it would meet the wishes of the Council. He thought that, as a general rule, they had quite as good appliances as any in England, and he thought these should be described as well as those in other parts of the country. The report, if issued in its present form, would look as if they had nothing of the kind in Scotland, and if each member who had coal-picking or other screens would describe and give a sketch of them, they would be incorporated in the report.

Mr JAMES HASTIE said, after the remarks of the Chairman, the Committee should not conclude their report until they saw the machines in use in Scotland. If the Committee sent word to the respective collieries, the owners would be as glad to receive them as in England.

Mr HUGH JOHNSTONE said a general circular was apt to be laid aside. Perhaps they should communicate with different owners, and ask permission to visit their collieries in order to see the machines in use at them, and have descriptions of them incorporated in the report.

The CHAIRMAN said it would be a simple thing for each member to send in a description and sketch as suggested. It took much time to visit the collieries, and the members of Committee had not only devoted a deal of time in doing that, but had to get up plans and reports. He thought it would be quite as well done if the owners or managers would send in a description of the machines they had at work. He intended to do so himself in two instances, and he thought this might be done generally.

Mr HASTIE said he was of opinion that a circular was of no use, and that if the Committee asked liberty to see and describe the machines, in most cases it would be granted.

The SECRETARY said Mr Hastie was too readily assuming that the Committee had all the time in the world to spare, and it was surely the duty of the members of the Institute to meet the Committee half way.

Mr SMART said Mr Johnstone's remarks as to a general circular were to the point. He thought some more direct method should be adopted.

The CHAIRMAN expressed the hope that, when this discussion was printed in the Transactions, members present and absent would send descriptions of their screening appliances to the Committee.

THE MINING INSTITUTE OF SCOTLAND.

SUMMER MEETING, 22ND AUGUST, 1889.

MEMBERS from Glasgow, Hamilton, and the West, numbering seventy-five, were conveyed in special carriages by Caledonian Railway to Edinburgh, where they were joined about eleven o'clock by others from Edinburgh district. Taken in brakes to Forth Bridge, the party was further augmented there by members from Fifeshire, and now numbered about 120.

Through the kindness of Mr Arrol, they were conducted over the works, inspecting first the engineer shops, where all the steel work of the bridge is shaped and fitted before being put into place; and the drawing hall, on the floor of which the several parts of the structure had been drawn out in detail on a large scale. Here, by means of models, the visitors were shown the ingenious method devised to overcome the difficulty at the meeting of the cantilevers and girders on account of expansion and contraction caused by changes of temperature. It was particularly interesting to observe that not only is expansion and contraction to the extent of 18 inches on the line of the bridge at the several points of junction provided for, but also a sideways movement of six inches, which such a circumstance as a cold wind blowing on the one side of the bridge and a hot sun beating on the other would produce. The provision made for the rails being kept straight, continuous, and safe in such a case was also shown—its simplicity no less than its ingenuity being noticeable.

Proceeding to the bridge itself by way of the jetty, which is carried out to the base of the first cantilever, the party had an

offer to be hoisted to the top of the structure, and nearly all took advantage of the opportunity. During the ascent and descent, as well as while on the top—360 feet above the surface of the water—a view was got of the details of construction alike novel and impressive.

Boarding a steamer, which was placed at the disposal of the party for an hour, they were taken across the Firth, and were enabled to view the structure from many points. Perhaps from no situation better than the deck of a steamer at a short distance above the bridge do the boldness of conception and magnificent proportions of the undertaking forcibly impress an onlooker.

Regarding the principle of construction, the illustration on Plate V., and the following extract from a lecture delivered at the Royal Institution in 1887 by Mr Baker, one of the designers of the bridge, will be specially interesting :—

"It is not on account of size only that the Forth Bridge has excited so much general interest, but also because it is of a previously little known type—I will not say novel, for there is nothing new under the sun. It is a cantilever bridge. One of the first questions asked by the generality of visitors at the Forth is : Why do you call it a cantilever bridge ? I admit that it is not a satisfactory name, and that it only expresses half the truth, but it is not easy to find a short and satisfactory name for the type. A cantilever is simply another name for a bracket, but a reference to the diagram will show that the 1700 feet openings of the Forth are spanned by a compound structure consisting of two brackets or cantilevers and one central girder. Owing to the arched form of the underside of the bridge, many persons hold the mistaken notion that the principle of construction is analogous to that of an arch. In preparing for this lecture the other day I had to consider how best to make a general audience appreciate the true nature and direction of the stresses on the Forth Bridge, and, after consultation with some of our engineers on the spot, a living model of the structure was arranged as follows (*see* Plate V.) Two men sitting on chairs extended their arms and supported the same by grasping sticks butting against the chairs. This represented the two double cantilevers. The

central girder was represented by a short stick slung from one arm of each man, and the anchorages by ropes extending from the other arms to a couple of piles of bricks. When stresses are brought on this system by a load on the central girder, the men's arms and the anchorage ropes come into tension, and the sticks and chair legs into compression. In the Forth Bridge you have to imagine the chairs placed a third of a mile apart, and the men's heads to be 360 feet above the ground. Their arms are represented by huge steel lattice members, and the sticks or props by steel tubes 12 feet in diameter and 1¼in. thick. I have remarked that the principle of the Forth Bridge is not new. When Lord Napier, of Magdala, accompanied me over the works one day he said: 'I suppose you touch your hat to the Chinese?' and I replied 'Certainly,' as I knew that a number of bridges on the same principle had existed in China for ages past. Indeed, I have evidence that even savages when bridging in primitive style a stream of more than ordinary width have been driven to the adoption of the cantilever and central girder system, as we were driven to it at the Forth. They would find the two cantilevers in the projecting branches of a couple of trees on opposite sides of the river, and they would lash by grass ropes a central piece to the end of their cantilevers, and so form a bridge. This is no imagination, as I have actual sketches of such bridges taken by exploring parties of engineers on the Canadian, Pacific, and other railways; and in an old book in the British Museum I found an engraving of a most interesting bridge in Thibet upwards of 100 feet in span, built between two and three centuries ago, and in every respect identical in principle with the Forth Bridge. When I published my first article on the proposed Forth Bridge, some four years ago, I protested against its being stigmatized as a new and untried type of construction, and claimed that it probably had a longer and more respectable ancestry even than the arch. The best evidence of approval is imitation, and I am pleased to be able to tell you that since the first publication of the design for the Forth Bridge practically every big bridge throughout the world has been built on the principle of that design, and many others are in progress."

Plate VI. is a copy of drawings of the Bridge, illustrating a

paper read by Mr Biggart in November, 1884, before the Institution of Engineers and Shipbuilders in Scotland, to which paper members are referred who desire information on the details of construction, and machinery and tools employed therein.

At a meeting of the shareholders of the Forth Bridge Railway Company, held two days before the visit, it was stated that the total expenditure up to that time had been £3,014,437 1s 2d.

Having spent 2½ hours at the Bridge, the party left at three o'clock, returning to Edinburgh by way of Dalmeny Park, the liberty to drive through which had been kindly granted by Lord Rosebery's factor.

The annual dinner took place in the Waterloo Hotel, Edinburgh, at 4.30. John M. Ronaldson, Esq., President of the Institute, occupied the chair, and Messrs Smart and Atkinson were croupiers.

Immediately after dinner there was held a

GENERAL MEETING.

JOHN M. RONALDSON, Esq., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary and confirmed.

The PRESIDENT said he was sure they had all been well pleased with their excursion. Those of them who had not seen the Forth Bridge before, but had heard of it, might truly say "the half hath not been told us." Their thanks were due to the contractors who gave them permission to go over the works, and to Lord Rosebery for permitting them to drive through the beautiful grounds of Dalmeny. (Cheers.) He thought they ought to be proud of their Scotch engineers when they saw such a wonderful undertaking so near completion. (Cheers.) Probably many of them who visited the Bridge in its early stages five years ago were inclined to doubt whether the undertaking could be carried out. None could have any fear now when they saw the work so nearly approaching completion, and he hoped the next time they might have the pleasure of visiting the Bridge it would be to ride over it. (Cheers.) He saw present a number of faces that were seldom seen at their ordinary meetings, and he would just hint very gently that they would be very glad to see one and all of them there oftener. They were now a strong body, and it would do them all good if those he alluded to would kindly put in an appearance now and again, and take part in the discussions on their papers. (Cheers.)

The discussion of several papers read at former meetings was then adjourned, and the meeting separated.

The members from the West left Edinburgh by the 8.20 train, and so ended one of the most successful Summer Meetings that the Institute has had.

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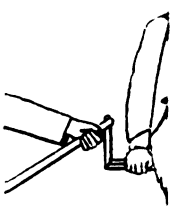

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,

10th October, 1889.

JOHN M. RONALDSON, Esq., President, in the Chair.

The minutes of the last General Meeting were read by the Secretary, and confirmed.

The following were elected by ballot as ordinary members:—

ALEXANDER GILLESPIE, Dalmellington Iron Works, Ayr.
WILLIAM P. PRENTICE, Dalmeny Works, Dalmeny.
HENRY KING, Darngavil Colliery, Airdrie.
JAMES CROSS, 445 Eglinton Street, Glasgow.
HENRY ROY, Pentland Works, Loanhead.
JAMES BAIN, Brownrigg Colliery, Longriggend.
ROBERT MURRAY, Blinkbonny, Bo'ness.
JOSEPH RUSSELL, Daldowie Colliery, Broomhouse.
JAMES CAMPBELL, Ballochmyle Colliery, Auchinleck.
JOHN M'BRIDE, Rawyards Colliery, Airdrie.
JAMES DICK, Drumsmudden Colliery, Ochiltree.

The following paper by Mr David Smith, on "Lightning entering Drumsmudden Pit Workings," was then read by the Secretary:—

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LIGHTNING ENTERING DRUMSMUDDEN PIT WORKINGS.

By David Smith.

Drumsmudden Colliery is near to the Ayr and Muirkirk Railway, 1½ miles above Drongan Station, and consists of two pits, each 200 fathoms deep, and 40 yards apart, having a large pumping engine and coupled winding engines, both under the one roof, and built on a stone seat. The height of chimney is 120 feet, and it is fitted with a lightning conductor, made of copper ⅞in. dia., about 5ft. long, with copper wire ⅜in. dia. attached. The pumping pit is 10 yards from the boiler stalk, and has a pithead frame 40 feet high, over which two pulleys are fixed, guiding the haulage ropes to the pit bottom. There is also a Guibal exhaust fan connected with this pit. On Wednesday morning, 21st November, 1888, a thunderstorm of unusual and alarming severity burst overhead, and a flash took place at a time when the ascending cage was within 20 yards from the surface. The engineman was made powerless by the electricity, but, fortunately, had the presence of mind to throw himself on the brake lever, and so stop the engine. When he recovered, he felt pained in arms, neck, and shoulders. Probably the fluid ran along the beam of the pumping engine, then down to the steam pipes which are connected to the winding engine, and along which it would find its way to the throttle valve handle. A heavy charge descended the conductor on the stalk, uplifting the earth and ashes at the bottom, but otherwise doing no damage. The pit bottomer of the winding pit heard a loud, cracking noise, and saw a clear, bluish flame on the crowns on the roof at the pumping pit. The signal boy was terrified, seeing fire running and leaping between the haulage rope and the rails. The chainman was engaged at the time taking down the empty race, and was sitting on the last hutch, with his feet on the chain. When about 40 yards down he felt a shock through his legs, and was pitched on to the road, and lay stunned for a time. Twenty yards beyond the foot of the slope dook, or 320 yards from the pumping pit bottom, and 240 fathoms from the surface, two boys were

standing, one having his feet on the rails and his head almost touching the electric bell wires. He got a shock, turning him round about, and both were terrified by seeing fire flying between the rails and wire. They ran off to find the oversman. When they found him they were white with fear, and said fire was flying all through the pit. Fortunately, no serious injury was done to any of the workmen or property by the above strange occurrence. Plate VII. shows the position of the shafts and mines, and the places where the different parties were affected. Two haulage ropes go down the pumping pit. At the end of one of these ropes the chain runner was struck. The other rope passes down to the inside dook, past where the boys were standing. The electric bell wires go from the haulage engine-house on the surface down the pumping pit, and past where the two boys were standing, on to the inside dook.

DISCUSSION.

Mr J. B. ATKINSON asked if this was given as an unusual occurrence in Scotland.

The PRESIDENT said they had had a case at Swinhill Colliery, which Mr Ralph Moore had brought before them, when he produced the miners affected by the shock.

The SECRETARY said there were cases that had occurred in England referred to on the same occasion.

Mr ATKINSON said there were several cases reported in the Transactions of the North of England Institute. An explosion of fire-damp in a disused lead mine near Hexham was thought to have been caused by lightning. The Risca Colliery explosion in 1880 occurred during a heavy thunderstorm, and it was suggested that lightning had entered the mine and ignited fire-damp.

The discussion was adjourned.

The following discussions then took place :—

DISCUSSION OF MR ROWAN'S PAPER ON "GAS FIRED BOILERS."

The SECRETARY stated that acknowledgment had to be made of the kindness of the proprietors of "Engineering" in supplying the blocks for figures 11 to 26 at a nominal price.

The PRESIDENT said one thing that struck him in regard to this paper was this:—Mr Rowan made out a favourable case for this gas firing, but they did not find very many people using it in practice. If that was so, there must be a reason for it. He would like to get at the bottom of that. He had heard it said that there was a difficulty with gas producers, such as the Wilson producer, in getting the air to go through the coal, especially when small coal was used. Of course, he was not speaking from personal knowledge—he was only speaking from what he had heard—and he regretted Mr Rowan was not present to give them his views on the subject. If gas firing was more economical than firing with raw coal, the question was, why was it not more universally applied?

Mr DAVID COWAN said he was sorry to say that he had not had time to carefully go over the paper, but it seemed to him to be a very complete consideration of the whole question. It was one of those questions to which he had given some little attention. He need not go through the whole of his experience in the matter, but the following, he thought, was a summary:—He made a very careful experiment with two Babcock and Wilcox boilers,—carefully measured the quantity of water that was evaporated in these boilers over a given length of time,—first while they were being fired with gas, and, second, while they were being fired with solid fuel, and the conclusion he came to was something like this:—That fuel in the solid state burned under these two boilers with which he had been dealing, evaporated about 10 per cent. more water than if the same coal was converted into a gaseous state and the gas burned under the boilers. On the other hand, they had, he might say, some saving in stoking, cleanliness, and regularity in firing; and, under certain conditions, he might say gas was preferable. In ordinary conditions, it made little differ-

ence, as regards economy, whether they used the coal in the gaseous state or in the solid state. If there were a great many points over an extended space where it was necessary to use fuel either in one form or another, it was sometimes more convenient to convert their fuel into a gaseous state and carry it through the works in pipes rather than have roads and other necessary appliances for taking in the solid fuel and taking away the ashes, and have a stoker for each set of fires. Under such conditions as these, he would certainly recommend gas to be applied. But gaseous fuel, like everything else, is no universal specific for all evils. These views of his were borne out, he thought, by a discussion that took place at the Iron and Steel Institute meeting at Paris, at which he was present, and in which he took a good deal of interest. There it was generally admitted that there was no advantage in firing boilers with gas made from the solid fuel—that gas had its specific purpose to serve, and in performing that purpose it certainly did very good service.

Mr JAMES GILCHRIST said, about three years ago, he went into the question of whether firing with gas or with solid fuel would be best. He did so not so much on the score of economy as for the prevention of smoke, and the result of his inquiries was that it would require about £1500 additional capital for six boilers, or £250 to put up plant and to make alterations to fire an ordinary Lancashire boiler. That was the reason why they did not go any further in the matter. It was far too costly. Of course, to other people who used a considerable number of boilers, and who had to pay a great deal more for their coal than was generally paid about a colliery, the question might be different. However, he thought the first cost prevented a great many people from considering the matter at all.

Mr HUGH JOHNSTONE said he thought Mr Gilchrist's estimate was rather above the mark. He had some experience about the same time with gas fired boilers. He had a 28 feet Galloway boiler, and two 30 feet Lancashire boilers in one battery; one of the Lancashire boilers was hand fired; the other Lancashire boiler and the Galloway boiler were fired with gas made in producers very similar to the Wilson producer. He required to use steam

at 90 lbs. pressure per square inch, and he found it impossible to maintain this pressure in the hand fired boiler with ordinary colliery dross. In order to do this, it was necessary to use riddled dross, which was rather a costly fuel. He found, as a matter of actual experience, that the cost of the plant was not up to what Mr Gilchrist said; and, further, the cost of firing showed about 30 per cent. in favour of gas firing, so long as he required with hand firing to use riddled dross; but as soon as he was able to bring back the pressure to 50 lbs., and to use ordinary dross the saving vanished, and the two methods were then nearly equal in cost. The difference being in favour of hand firing, the other was given up. That appeared to be the general experience, and in almost every case the gas producer had been given up.

The PRESIDENT asked how Mr Johnstone accounted for the saving with the gas disappearing when they altered the fuel.

Mr JOHNSTONE said the riddled dross was a much more costly fuel than he was enabled to use with the gas producer. It was commonly said that it would take gas out of an inferior fuel. It did so, but with an inferior fuel the labour was very much increased. If he used a better fuel, he made more gas at a cheaper rate so far as labour was concerned, but by utilising an inferior fuel he was able to show results 30 per cent. in favour of gas firing. However, as soon as he was able to bring back the pressure and hand fire with the ordinary dross the saving was gone, because the fuel used was the same as in the producer.

Mr COWAN said he could scarcely say that he could agree with Mr Johnstone as to his statement about the cost. He was more inclined to coincide with the ideas of Mr Gilchrist. After they had had a good deal of experience with gas, they found out an amount of outlay they never anticipated, and if all the items were added they would find the capital outlay would not be much less than £250 per boiler. However, in many cases, the plant was started on a cheap scale, and a good deal of alterations and other things were put into working expenses, and the real cost was seldom ascertained.

Mr JOHNSTONE said, of course, in his estimate he was assuming an entirely new plant to be laid down to fire new boilers, and that consequently the cost of patching and altering existing

arrangements was done away with. When they had a hard and fast plan for a new fitting to work on from the first, the work was carried on in a methodical way.

The CHAIRMAN adjourned the discussion to enable Mr Rowan to reply at next meeting.

DISCUSSION OF MR MOTTRAM'S PAPER ON A "PATENT PETROLEUM OR NAPHTHA ENGINE."

Mr MOTTRAM said he had written to the makers about the exhaust, thinking he might get some information from them. He called attention to the exhaust being objectionable, and they wrote saying that instead of using shale spirit if the engine was worked with American deodorized naphtha, which cost about 1d per gallon more, there would be comparatively no smell whatever. As regarded the working of the engine, he thought he would just like to know from the manager (Mr John Smith) whether it was as satisfactory as in the past. Mr Smith wrote on the 18th October:—

"Regarding the naphtha engine, it is doing very well, and I am quite satisfied with its work up to the present time. About two months ago the valve broke, and was replaced with a new one. The engine has gone well ever since, and gives no trouble. I have never tried the exhaust in a current of four or five thousand cubic feet per minute, but I am of opinion that the atmosphere would not be very much different from that where naphtha is used in safety lamps. The fan was idle five days lately. During that time the engine was kept going, and I had men employed near the bottom of the upcast shaft, about 400 fathoms from the engine. They made no complaint of having felt anything disagreeable at that distance, and I have not yet had an opportunity of making a test nearer hand."

Of course the naphtha emitted a peculiar odour, but the machine itself seemed to be working very well.

The PRESIDENT said this seemed to him a very convenient way of carrying power. A man might carry it under his arm to a distant part of the pit. However, a very objectionable thing would be to allow the exhaust air to go into the return air-course. Of course, if a large current was passing, the products of combustion in a small engine would be really infinitesimal, and the noxious fumes would not be bad, but they could understand a case where there was, perhaps, not a large current of air passing, and the engine using a good deal of naphtha, where the fumes would be objectionable. Again, in a fiery pit, it would be a most objectionable thing to introduce an engine of this description where safety lamps were in use. Of course, where naked lights were in use, that fell to the ground. He had not seen the engine, but it seemed to be a convenient method of lifting small quantities of water. He closed the discussion, and proposed a hearty vote of thanks to Mr Mottram for the trouble he had been at in preparing the paper.

DISCUSSION OF MR ANDREWS'S PAPER ON "AIR VESSELS."

THE Secretary read the following communication from Mr ALEX. EASTON, Wilsontown :—

A careful comparison of the observed results, given in Mr Dugald Baird's paper on Air Vessels, with the accompanying data, shows, I think, very conclusively that the necessity, and consequently the importance, of the air vessel depends to a great extent upon the imperfections of the pump itself.

Knowing that a second paper on the same subject was to be read by Mr Andrews, I, like many more, I believe, had great expectations that his treatment of the subject would, to use the words of Mr Dugald Baird, "throw more light into my very imperfect knowledge of the matter." I am sorry to say, however, that in this I have been very much disappointed. I am inclined to think that he has rather increased than diminished the fog of

"popular error" in which he seems to have found us. Mr Andrews, in quoting figures to show the beneficial effects due to having an air vessel of ten times the capacity of the pump, gives 297 lbs. per square inch as the greatest possible pressure in the case of the column of water not moving. Now, this is not quite correct; for let P be the pressure resulting from forcing a stroke of water into an air vessel already two-thirds full of air at 260 lbs. pressure per square inch, and calling the capacity of the pump C, we have, at commencement of stroke,

$$\text{pressure} \times \text{volume} = 260 \times \tfrac{2}{3} \times 10\,C;$$

and at end of stroke,

$$\text{pressure} \times \text{volume} = P \times (\tfrac{2}{3} \times 10\,C - C).$$

Accordingly, if we assume Boyle's law to hold, these quantities must be equal. That is,

$$P \times (\tfrac{2}{3} \times 10\,C - C) = 260 \times \tfrac{2}{3} \times 10\,C;$$

$$\therefore\ P = \frac{260 \times 20}{17} = 305{\cdot}8 \text{ lbs.}$$

The difference, no doubt, is not very great; nevertheless, when any one is giving figures to exhibit the *smallness* or the *greatness* of the effects claimed for any arrangement he is advocating, it is not considered very scientific to make the figures any *smaller* or any *greater* than they really are.

Perhaps the water, in its thirst for air under high pressure, has, like the soda water, swallowed as much air as to cause a reduction of 8·8 lbs. per square inch. But Mr Andrews does not say so, and we have no right to assume it.

Mr Andrews has hit the right nail on the head when he says that "the purpose of an air vessel is to counteract or qualify the *vis inertia* of the water." But before proceeding further, it may not be out of place to explain the meaning of this mysterious looking term, *vis inertia*, and to ascertain, if possible, upon what its magnitude depends; or, as Mr Andrews put it, what it "relates" to, in the case of a vertical column of water. By *vis inertia* is meant that inherent property of all matter whatever, in virtue of which it resists any attempt to change its state of rest or of uniform motion in a straight line; and this resistance, in the case of a vertical column of water, is measured by the

statical pressure, due to the *height* of the column, and by the rate at which the speed or velocity of the rising column is changed. For example, suppose we have a pump the area of which is equal to that of the rising main pipes, then the weight of water in the column will just be equal to pressure multiplied by area of plunger, and the *vis inertia* will be proportional to the pressure multiplied by the area of the plunger multiplied by the acceleration of speed of the plunger. Now, suppose that, instead of the rising main having the same area as that of the plunger, its area is only one-half of that—not an uncommon thing in practice—and that the same quantity of water is to be pumped in the same time as before, which is the same thing as saying that the speed of the plunger is to remain the same. Then, speed of rising column is equal to twice the speed of the plunger; consequently, if the speed of the plunger changes from O to V in any time, the speed of water in column will change from O to twice V in the same time; therefore, the resistance of the rising column is proportional to the pressure multiplied by the area of the discharge pipes multiplied by the acceleration of twice the speed of the plunger, or is proportional to the pressure multiplied by area of plunger multiplied by the acceleration of the speed of the plunger. Hence it follows, from the law of equal transmission through a fluid, that the resistance, or *vis inertia*, as felt on the plunger, will now be proportional to the pressure multiplied by the area of the plunger multiplied by twice the acceleration of speed of the plunger, which is exactly *double* of what it was in the first case, and yet we have only *half* the *weight* of water we had in the first case. Again, since the acceleration is equal to the change of speed or velocity divided by the time taken to produce this change, it is evident that time is just as important an element as change of speed in bringing into play *vis inertia*, so that the statement of Mr Andrews that "*vis inertia* has no relation to pressure—it relates only to the weight of the body and the speed it is going at if it has to be stopped, or the speed it must attain if at rest," is palpably absurd. Mr Andrews is not even consistent with himself, for, when giving a calculation to illustrate how an air vessel designed according to his rule would "counteract" the *vis inertia* of the water, he bases the calculation on the statical

pressure of the water. But since "*vis inertia* has no relation to pressure," it therefore follows that his calculation proves *nothing* relating to *vis inertia*.

Seeing that *vis inertia*, so far as a pit pump is concerned, is directly proportional to the statical pressure, to the area of the plunger, to the ratio of the area of the plunger, to that of the discharge column, to change of speed, and inversely proportional to the time taken to produce that change, I do not think that it is too much to say that any rule which is offered for the capacity of an air vessel, and which does not embody all these factors, if not a delusion and a snare, is, at least, worse than no rule at all, and altogether out of keeping with the scientific spirit of our times.

Curiosity led me to apply this rule just to see what would be the dimensions of an air vessel to suit a plunger lift I have charge of. Diameter of plunger = 28ins., stroke = 6ft., so that ten times capacity would be $= 10 \times \cdot 7854 \times (\frac{28}{12})^2 \times 6$ cubic feet. Outside diameter of rising column = 27ins. Supposing the air vessel to be put on the main column, as Mr Andrews suggests, let D = the diameter of the inside of the air vessel, which, we will suppose, is 9ft. long inside, the capacity of this air vessel will be =

$$\cdot 7854 \times \left\{ (\tfrac{D}{12})^2 - (\tfrac{27}{12})^2 \right\} \times 9 \text{ cubic feet,}$$

And

$$\cdot 7854 \times \left\{ (\tfrac{D}{12})^2 - (\tfrac{27}{12})^2 \right\} \times 9 = 10 \times \cdot 7854 \times (\tfrac{28}{12})^2 \times 6$$

$$\therefore \; D = 77\text{ins. fully.}$$

The pipes are $2\frac{1}{2}$ins. thick, and, in order that the air vessel may be equally strong, its thickness must be, at least $= \frac{77 \times 2\frac{1}{2}}{22} = 8\frac{3}{4}$ins, so that our air vessel would be 11ft. high, 8ft. diameter, and would weigh over 50 tons. How this could be got into its place in the shaft is a problem which Mr Andrews may solve.

Mr DUGALD BAIRD communicated as follows:—I am glad to find my paper on air-vessels followed up by another on the same subject and by such a good and experienced authority, for I am sure that the subject is well worthy of much consideration.

On page 113, line 14, he blames me with having fallen into popular error; so far as I can judge I attacked every known form of popular error, including those forms that he himself attacked.

Further down on the same page he says that an air-vessel of four times the capacity of the ram is really of little use. My diagrams

No. 3 and 4, although taken from a pump whose air-vessel is only three times the capacity of the ram, shows a clear reduction of 47 per cent. of pressure, which speaks for itself.

I admit at once that a tenfold capacity air-vessel is better than a four-fold capacity one; but better have a fourfold one than none at all, because it is not always easy to get a tenfold one on. Take one inconvenience. Given an underground pumping engine with an 18-inch ram and a 7-feet stroke (and there are many larger) and it is wished to put on a tenfold air-vessel. What will it cost? With an inside diameter of 3 feet and a factor of safety of 15, the thickness of metal would require to be 4½ inches to resist a vertical column of 100 fathoms; the height of the air-vessel would require to be 17½ feet, and the total weight, including flanges, about 15 tons, which at £8 per ton is £120, to which has to be added the cost of making a place to hold it, and the fixing up; and if the form of air-vessel recommended on page 117, line 8, be adopted, the cost for the bare casting would be £170. A fourfold capacity air-vessel appears to me to be a very convenient and efficient size, provided it is kept charged. And this applies to all sizes.

In page 117, line 8, the vertical, internal tube air-vessel without the cup is recommended. No doubt this is a good form of air-vessel, and no doubt the water will make an easier passage without the cup; but Mr Andrews does not show how it is possible to get air into the air-vessel, seeing that he admits it by means of an air cock on the suction pipe. I fear the whole of the air will pass straight up the column and escape at the surface, leaving the air-vessel useless.

On page 118, line 15, he condemns the use of an air-vessel half way up the column as "preposterous in the extreme," but qualifies this at line 30 of the same page by admitting that it may do half work. Now, surely half work is very fair, and might be the means of much relief to an overburdened pump, there being, of course, if at all possible, an air-vessel as close up to the discharge valve as practicable. I am of opinion that intermediate air-vessels are very good on long columns.

On page 118, at line 33, he says Cornish and other pumping engines of the direct acting class have no need for an air-vessel,

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and he gives as the reason why, because the rods, if properly proportioned, cannot force the water up beyond the proper speed. Now, what is the proper speed? That will depend on the growth very likely, and whether or not the proper speed may be large enough to require an air-vessel to take in part of the delivery, which it can discharge into the column during the upstroke of the ram. Again, when a direct-acting engine comes on air, the ram having nothing to support it at the top stroke, immediately the steam leaves the underside of the piston, it will fall with the full force of gravity on the heavy rods, and strike the water much harder than if the engine was a rotary one, because in that case the inertia of the fly wheel and the rest of the machinery would retard the blow; showing that the direct-acting engine has most need of an air-vessel. But both classes of these engines require air-vessels, because the fly wheel in many cases may force the water out of the casing in a particular time, irrespective of what pressures are created, whereas if a little more taking and giving were allowed, abnormal pressures would be obviated.

Mr JOHN DRINNAN said he thought they were all agreed in welcoming every contribution on the subject which this paper discussed, because it was certainly one of some importance to all those engaged in mining operations. But he thought this Institute would be unworthy of itself if it did not seek to carefully examine the papers submitted in order to insure that their Transactions would be the record not of fallacies but of carefully ascertained facts. There were one or two matters to which he wished to call attention in connection with this, although some of them had been taken up in some of the contributions they had just heard read. However, he did not think they need have much hesitation in discussiug this subject at greater length, because the author of the paper did not hesitate himself to declare of the paper previously read on the subject, and the subsequent discussion that took place thereon, that it was characterised or tempered with a modicum of popular error. He went on afterwards to seek to prove that water absorbed air. Now, while none of them could lay claim to the life-long experience of Mr Andrews, or his ripe wisdom, he thought they might lay claim to some knowledge on this and kindred subjects,

and without the aid of soda water or other illustrations they would be ready to admit that unless some provision was made for recharging the air-vessels they would soon cease to fulfil the purposes for which they were designed. One of the purposes for which he had risen was to call attention to the fact that in making a comparison of small and large air-vessels Mr Andrews instituted what he considered a most unfair comparison, and one which he thought was altogether misleading if his object was to arrive at the relative merits of each. For instance, in speaking of an air-vessel which was four times the capacity of the pump, he sought to prove that before the water could be raised to the height of one hundred fathoms the air space available in the air-vessel would not be more than one-tenth of the capacity of the pump; but in order to obtain the result he had supposed a number of conditions which he afterwards himself confessed to be abnormal and altogether improbable. In dealing with a large air-vessel he charges one with air to such an extent as to have two-thirds of it filled with air at the statical pressure due to a hundred fathoms, and then he sought triumphantly to declare that an air-vessel in such a condition would hold a full stroke of the pump without the water in the rising main ever being moved. No doubt that was true, but then it was equally true of a small air-vessel if he had treated it in a similar manner; and to prove this it was only necessary to say, if they had a pump, say with a capacity of six feet, and an air-vessel with a capacity of twenty-four feet, then two-thirds of the air-vessel would be sixteen feet, which would be between two and three times the capacity of the pump! so that, if they were to make a comparison between the two, it seemed to him the only point of inferiority would be in a more speedy exhaustion of the air in the small air-vessel. There was another matter he would like to call attention to, viz.:—Mr Andrews assumed that an air-vessel could not be too large, neither could it be too highly charged with air. Well, both the contributions read had made some reference to that, and consequently it was hardly necessary for him to say anything. The larger the air-vessel the greater the cost of fitting up, and if they had no corresponding advantages for all this cost then that air-vessel was too large. They would

accord a considerable privilege to age; still he was inclined to think, from all Mr Andrews had stated, he had been underrating a little the knowledge of the members on air-vessels and other matters connected with mining.

Mr D. M. MOWAT said he did not quite agree with the putting on of a small pet cock on the suction pipe. He had tried it and it did not work. The air accumulated at the top of the working barrel, and did not get out, and caused the pump to strike heavily. It would only do when the discharge valve was at the top end of the barrel of the pump. With regard to what Mr Drinnan said about the small and the large air vessels, he thought he was not quite correct. The advantage of the ten times compared with the four times was not only that the air would last longer, but that the increase in pressure when the water entered the larger air vessel would be less than with the smaller one, and consequently there would be less shock. There was another thing he did not mean to mention, because it was rather paradoxical, and he was inclined to leave it out. The pump he spoke about in the discussion on Mr Baird's paper had been altered since. A larger pump had been put in. The pump which was in before worked splendidly, but this larger one only pumped in the reverse stroke, and there was no discharge during the down stroke. There was nothing that he could see to account for it. It appeared to have too many air vessels, but he did not think that was the case.

Mr JOHNSTONE asked if they had ever tested whether the pump was discharging a quantity of water proportionate to the capacity of the ram.

Mr MOWAT said it could not help doing that. It was a perfectly good ram. He thought the pump was pumping the full water. There was no leakage.

Mr DRINNAN apprehended the air in the air vessel was only at atmospheric pressure. It would be very interesting if Mr Mowat had any means of testing it to see how it would act if it was charged with air to the statical pressure of the height the water was to be raised. It was discharging itself into the air vessel simply because it met with less resistance there, but he did not

think it would be so if the vessel was charged with air so as to give it a statical pressure equal to the height the water was to be raised.

Mr MOWAT said the air in the air vessel was at the statical pressure after it began to work. It was not starting with air at the statical pressure.

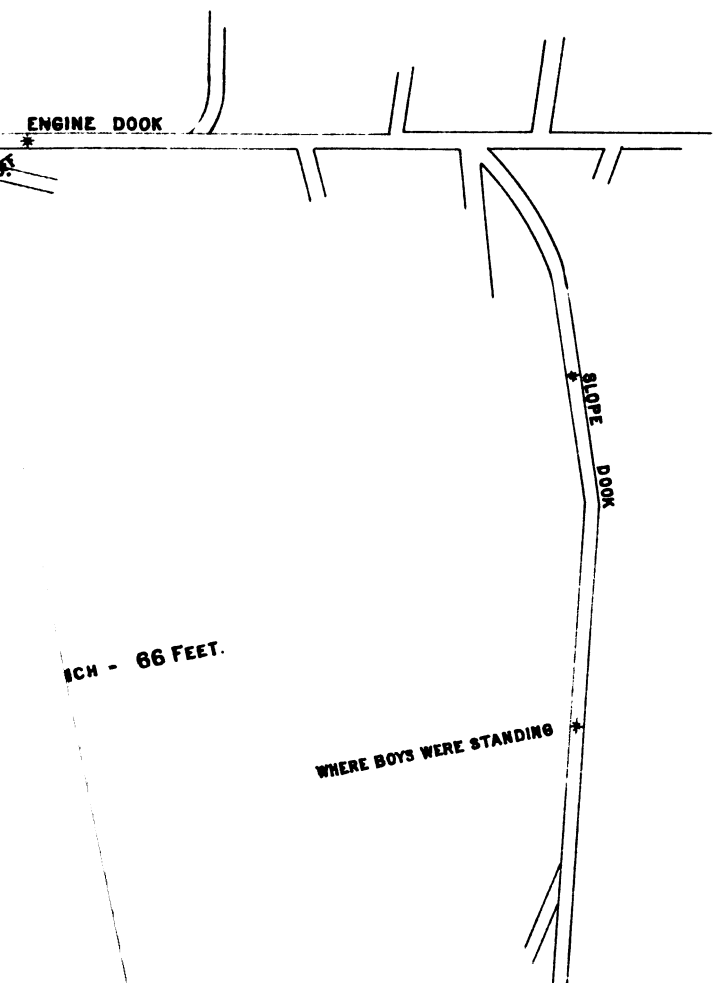
The discussion was adjourned.

FIRE EXTINGUISHER DISPLAY.

ON the invitation of Mr John Tennent, 12 Montrose Street, Glasgow, members were afforded an opportunity of seeing the effect of Lewis's Hand Tube Fire Extinguisher. The liquid is enclosed in tubes of the capacity of about a quart, and on the lid being wrenched off it is ready for use by being thrown or sprinkled on the fire. It was stated by the exhibitor that as soon as the liquid touches the fire a gas is given off which is more effective than the liquid itself, and that this gas is harmless to life. No particulars were furnished of the composition of the liquid, or reasons given for the gas being harmless. On the small scale on which the trials were made the extinguisher seemed effective. A hand pump to be used with the liquid in bulk for a large fire was also shown.

M.T.S.

h's paper on
MUDDEN PIT WORKINGS.



THE MINING INSTITUTE OF SCOTLAND.

COMMITTEE ON COAL-CLEANING.

THE Council of the Institute, at a meeting held on 18th October, 1888, appointed a committee of members of the Institute to visit collieries in Great Britain; examine machines and methods of cleaning, sorting, and preparing coal for the market; and report to the Council. The committee was composed of the following members:—Messrs Jas. Barrowman, secretary (convener); Charles Carlow, managing director of the Fife Coal Coy., Leven; David Cowan, general manager to Carron Coy., Falkirk; James S. Dixon, M.E., Glasgow; James Gilchrist, manager, Earnock Colliery, Hamilton; A. M. Grant, engineer, Kilmarnock; Jonathan Hyslop, M.E., Airdrie; David M. Mowat, M.E., Summerlee Iron Works, Coatbridge; Samuel Potts, engineer, Burnbank, Hamilton; John Smith, manager, Cannock Lodge Colliery, Bloxwich, Staff.; and Wallace Thorneycroft, of the Merryton Coal Coy., Hamilton.

The Council have now the pleasure of submitting to the Institute the following report of their committee.

REPORT OF THE COMMITTEE.

With the view of carrying out the remit of the Council, the Committee communicated with Her Majesty's Inspectors of Mines in the colliery districts of England and Wales, in order to ascertain where good examples of the various systems of coal cleaning were at work. This information was readily furnished by the Inspectors, through whom also introductions were had to the owners and managers of the several collieries.

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The members of Committee then arranged their number into three divisions, and set apart a district to be visited by each. Messrs Dixon, Grant, Smith, and Thorneycroft were allotted to South Wales; Messrs Cowan, Gilchrist, and Hyslop to Sheffield, Nottingham, and Manchester districts; and Messrs Barrowman, Carlow, Mowat, and Potts to Newcastle and Cumberland districts. Mr Barrowman and Mr Carlow were unable to go at the time arranged, but Mr Carlow's manager, Mr Dugald Baird, went for him, and Mr Barrowman undertook the work of collecting reports from collieries in Scotland.

When the reports of the various sections had been sent in and examined by the Committee, it was considered that the simplest, and, perhaps, on the whole, the most satisfactory form for the report to take, was to describe separately the arrangements at each colliery by itself, instead of attempting a classification according to the various systems; because at several collieries more systems than one are in operation, and to classify according to systems would have led to some repetition, and possibly confusion. Each section of the report is, therefore, separate and independent of the other. To facilitate reference to examples of the several systems, an index is printed at the end of the report.

The Committee have to record their sense of the valuable assistance given by H.M. Inspectors of Mines in the several districts visited, and the courtesy and kindness with which they were received by the owners and managers of the collieries. The descriptions of examples of coal-cleaning in Scotland which appear in the report were either offered by members of the Institute connected with the collieries referred to, or readily given when asked for, and the Committee have to acknowledge the kindness of those who have furnished these particulars.

SOUTH WALES.

CWM-AVON WORKS.

THE coal washing machinery at these works is on the felspar system, and is used to wash dross for coke-making. The machinery, of which the following is a description, was constructed and erected by Messrs Evence Coppee & Co. of Cardiff. Drawings of it are shown on Plates VIII. and IX.

The small coal arriving from the mines is delivered into the pit, *A*. An elevator, *B*, takes it up and delivers it to the screen, *C*. This screen is provided with round perforations of ¾in. and ⅜in. diameter; therefore, the sizing is as follows:—

From ¾in. upwards.
From ¾in. to ⅜in.
From ⅜in. downwards.

The first two of the above sizes are washed in the "bash" nut coal washers, *E* and E^1, and after being washed are brought by means of water through the shoot *F*, upon the draining screens *G*, after which they accumulate in the bunker, *H*, from which they are loaded into the truck H^1. The water passes through the screen *G*, and goes through shoots to the basin *J*.

The refuse or dirt of the nut coal washers is taken a few feet up by the small elevator, *O*, which delivers it by a shoot into the shale basin, *P*.

The coal of ⅜in. downwards is sent by water into a screen, *D*, which is provided with perforations of ¼in. and ⅛in. diameter, so that the coal is sized as follows:—

From ⅜in. to ¼in.
From ¼in. to ⅛in.
From ⅛in. downwards.

These are washed separately in four felspar washers $I.I^1I^2I^3$. The intermediate being most abundant is washed in the two washers I^2I^3. The coal, after being washed over the felspar, accumulates in the coal basin *J*, in the bottom of which there is a screw *K*,

which delivers the coal into the bunkers *M M*, whence it is taken to the coke ovens. The rubbish from the felspar washers is carried by shoots to the shale basin *P*, from which an elevator, *Q*, raises the whole of the rubbish and delivers it into the bunker *R*, where it is taken by trucks *S* to the tip.

At *X* is shown the position of the coal crushing machine, and at *V* that of the elevator for taking up the crushed coal. This part is not yet erected, but provision is here made for it if required.

The centrifugal pump *U* sends the water to the upper screen *C* and to all the washers. And it must be here noticed that the dross is damp before being delivered to the washer, and in this state would not size in the screen; and it is for this reason that a jet of water is sent into the screen, so that the dross may be thoroughly separated. The overflow water from the shale basin *P* runs into the basin *W*, then into the basin *J*, in which the dirt is deposited. It then flows into the well *T*, from which it is raised by the centrifugal pump *U*, and led by means of cast-iron pipes back into the washers.

The steam engine *V* is horizontal, and drives the whole system: cylinder, 21in. diameter; stroke, 42in. There is sufficient power in the engine to drive the crusher when put up.

There are three boilers, each 28ft. long and 5ft. 6ins. diameter, and supplying steam at 40lbs. The boilers are fired by the waste gases from the coke ovens, and the feed water is heated to about 212 degrees. The centrifugal pump is 18ins. diameter, and was working at a speed of 845 revolutions per minute. This pump circulates the water from the well *T*, and replenishes the waste that escapes with the washed dross and shale. The delivery pipe is 7ins. diameter.

The screen *C* at the top is made of plates with perforated holes, and a 2in. malleable iron pipe for supplying water to wet the dross is led into the shoot that delivers the coal from the elevator to the top end of the screen. The diameter of the screen at the top is 5ft. 4ins., and at the opposite end 6ft. 8ins., the shaft being level. The total length of the screen is about 12 feet, and the speed 12 revolutions per minute.

The screen *D* is also about 12 feet long, and is formed of malle-

able iron plates with perforated round holes. The diameter next the shoot is 3ft. 3ins., and at the delivery end 4ft. 6ins.; speed, 8 revolutions per minute.

Three tons of washed dross produce two tons of coke, costing about 7d per ton for labour at the works.

The coal washing plant is situated at a considerable distance from the mines and close to the coke ovens and Cwm-Avon furnaces.

The dross is obtained from eight different seams of coal, varying in thickness from 1ft. 8ins. to 3ft. 6ins., worked on the longwall system with open lights, and the colliers are subject to a system of fines for sending up dirt.

The coal is tipped over simple screens, having bars 20ft. long and 1½in. apart; and from 60 per cent. to 75 per cent. passes through, the remainder being used without further handling as house coal. The following table, which was supplied by Mr John Stevenson, the engineer for the company, shows the average characteristics of each seam, and the results of washing:—

Names of Seams.	Average Thickness.	Ash in Sample taken in Average Hutch.	Ash in Pure Round Coal.	Specific Gravity of Coal.	Average sp. gr. of dirt from all seams, 2·486.	Ash in nuts ⅜in. and over, not coked.	Ash in nuts ⅜in. and over, coked.	Ash in coal below ⅜in., coked.	Ash in coke (30 cwts. coke per ton of coal).
	Ft. In.								
Golden Seam Rider, -	1 8	11·50	2·02	1·294					
Cwm Mawr Seam, - -	1 8	2·50	1·85	1·305					
White Seam, - - - -	3 6	19·25	2·85	1·309					
Tor-y-Mynydd Seam, -	2 2	12·80	1·93	1·318					
Jonah Seam, - - - -	—	15·50	3·28	1·306					
Cwm Byr Seam, - -	1 9	8·80	3·13	1·284					
Wern Pistill Rider, -	2 0	15·59	1·92	1·290					
Wernddu Rider, - -	2 2	9·80	1·21	1·287					
Average, - - - -	...	11·97 Say 12	2·27	1·299	...	1·85	2·35	5·23	6·38

The average quantity of dirt in the mixture of the dross sent to the washing machine was said to be from 15 to 18 per cent. At the time of our visit the machine was just started, and was not running up to its full capacity. The dross was shovelled from waggons into the elevator pit, but hopper waggons were being built, so that the dross may be delivered directly to the elevator.

The large nuts are used in gas producers, and the small nuts and gum for coke making.

The two sizes of nuts, the gum, and the dirt are all delivered into their respective hoppers before being dropped into waggons or bogies. The dirt is taken away in ordinary waggons, and emptied by hand. This latter arrangement will probably be improved on and the labour saved, when the washing plant is longer in use.

We saw a few pieces of dirt among the nuts, but the gum appeared to be very clean. The following analyses show very good results:—Ash in nuts over ¾in. screen, 1·85 per cent., not coked; ash in nuts over ¼in. screen, 2·35 per cent. coked; ash in gum, 5·23 per cent. coked; ash in coke requiring 30 cwts. raw coal per ton of coke made = 6·38 per cent. = 4·26 per cent. ash in raw coal. The dirt contained an appreciable quantity of small coal.

The number of men required to work the machinery, exclusive of emptying or filling waggons or disposing of the dirt, was as follows:—One man attending engine, centrifugal pump, &c.; one man attending on the upper floor, that is on the first revolving screen and bash washer for the larger sizes of coal; and one man attending the felspar machines in which the smaller sizes are treated, or, in all, three men.

We were informed by Mr Stevenson, who, in the absence of the general manager, Mr S. Danks, conducted us over the works, and gave us every possible attention, that the cost per ton for labour was under ¾d. Mr Stevenson also supplied the following information as to the cost of the plant:—

Cost of the Installation of Coppee Coal Washing Machinery and 40 Coke Ovens.

Washing Machinery,	£1700	0	0
Forty Coke Ovens, including discharging ram, water pipes in front of ovens, and erection of ovens, all ready for work,	3700	0	0
Work done by the Cwm-Avon Company, consisting of building for coal washer, roofing, joiner work, sidings, excavations, charging hopper, water pipes, engine, boilers, &c.,	3800	0	0
	£9200	0	0

It was not possible for the Company to give us any data as to the cost of the upkeep of the washing plant, as to repairs, furnishings, etc., either per annum or per ton, the plant having been only a week or two at work.

For a new plant the whole of the machinery was washing very well indeed, the Cwm-Avon Company being well pleased with the work, so far as it had gone, the effect of which was already being felt in a more economical working of their blast furnaces, with a better quality of produce from them than with their old system of washing and coke ovens.

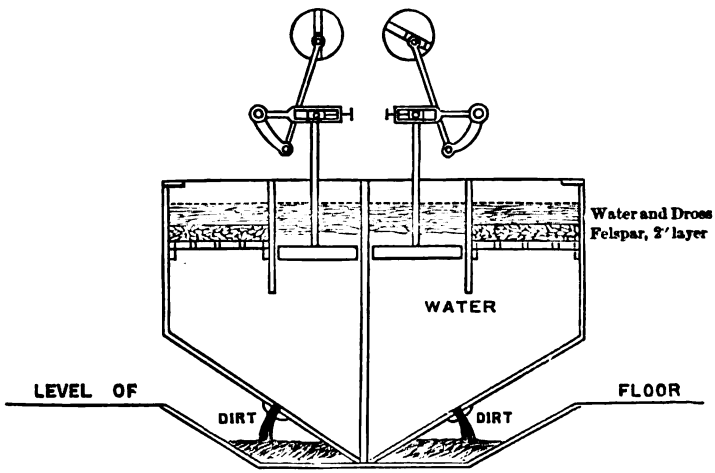
DOWLAIS WORKS.

THE plant here is very extensive and elaborate, and is capable of washing 1000 tons per day of 10 hours. It was erected by Messrs Evence Coppee & Co., limited, of Cardiff, and is of a similar design to the arrangement seen at Cwm-Avon, but much larger. The description given in the paper written by Mr R. De Soldenhoff, of the Evence Coppee Company, and published in the proceedings of the South Wales Institute of Engineers (vol. xiv. pp. 88-103), is in every essential particular most accurate, and could, with confidence, be adopted by this Committee.

CELYNEN COLLIERY.

THE NEWPORT ABERCARNE COLLIERY COMPANY.

PLATE X shows a drawing of the whole plant at this Colliery, of which the following is a description :—The washing machinery is designed to wash 200 tons in 10 hours. The unwashed coal is brought from the colliery screens by a creeper or revolving screw



A, situated in a cast iron trough set in bricks and cement, to the coal pit *B*, from which it is taken up by an elevator *C*, to the screen *D*. This screen sizes the coal as follows :—

(1) From the coarsest size to $\frac{3}{4}$in.
(2) From $\frac{3}{4}$in. to $\frac{3}{8}$in.
(3) From $\frac{3}{8}$in. downwards.

The first two sizes are washed in the two nut coal washers *FF*[1], an enlarged drawing of which is here shown, after which the washed nuts flow over the gauze table, and, being there deprived of the water, are directed to the crusher *H*. The crushed coal is taken up the elevator *I*, which raises it to the bunkers *JJ*. The refuse of the nut coal washers is carried forward by the screw to the foot of the elevator *H*[1], which raises

it and drops it into a trough leading to a rubbish cistern *L*. The coal under $\frac{3}{8}$in. is sent to the revolving screen *E*, which sizes it as follows :—

(4) From $\frac{3}{8}$in. to $\frac{1}{4}$in.
(5) „ $\frac{1}{4}$in. „ downwards.

The coal $\frac{3}{8}$in. to $\frac{1}{4}$in. is washed in the felspar washer *M*, whilst the coal under $\frac{1}{4}$in. is washed by the washer M^1. The coal from the washers *M* and M^1 drops into the basin *N*, whence the screw *O*, situated in the bottom, carries it to the elevator *P*, which raises the washed coal to the bunkers *JJ*, where ultimately the fine coal below $\frac{3}{8}$in. gets mixed with the crushed fine coal. The rubbish from the washers MM^1 is sent by troughing to the rubbish cistern *L*, and is mixed with the rubbish of the nut coal, and is raised outside the building by an elevator *Q*. The centrifugal pump *T* supplies the water to the washer. The water, after washing the coal, collects in a basin, and the overflow from this basin flows into the centrifugal pump well *S*. The small steam engine *W* works the screw carrying the unwashed coal, while the steam engine *U* drives the whole of the machinery connected with the washing. This engine is horizontal, 14ins. cylinder, 2ft. 6ins. stroke.

The screw which takes the coal from the screens at the pit to the elevator at the washing-house is 60ft. long and 16ins. diameter; speed, 70 revolutions per minute. Upwards of 200 tons were easily washed in ten hours by this plant.

The screen at the top is about 10ft. long, 4ft. 6ins. diameter at the end next to the elevator, and 5ft. at the opposite end; speed, 8 revolutions per minute. The unwashed coal elevator has 204 steel buckets, and 44 buckets per minute tip over the top into the revolving screen. There are two pairs of rollers in the coal crusher, one pair being immediately over the other. Each roller is 12ins. diameter, going 160 revolutions per minute.

The pulsations in the felspar machine were 120 per minute, about 1in. stroke. The length of stroke can be varied. There are from ten to thirteen tons of rubbish taken from 200 tons of dross.

At Abercarne the average quantity of small coal or dross passed through the machine is 220 tons per day. The dirt in

the coal before being washed averages 10·5 per cent. There was only one seam being worked, the Black vein. The ash in the unwashed coal of different sizes is as follows, viz. :—In the nut coal, from 1¼in. to ¾in. round holes, 9·15 per cent. ; in the nuts, from ¾in. to ⅜in., 6·35 per cent. ; in the small coal, from ⅜in. downwards, 16·35 per cent.

The ash left in the washed coal is as follows, according to sizes :—The average in the nut coal from 1¼in. to ⅜in. is 6 per cent. ; in the coal from ⅜in. downwards it is 4·85 per cent. There are two men employed at the washing. One attends to the felspar washers and steam engine, and the other to the nut coal washers. The total cost of labour is slightly under ½d per ton.

The total cost of washing plant, including machinery, engines, bunkers, belts, and all complete was £2500.

The sizes of the tubs at Abercarne Colliery were as follows :—5ft. 1in. long by 3ft. 3ins. wide at the top, and 5ft. 1in. long by 2ft. 4ins. wide at the bottom; 2ft. 6ins. deep; 14ins. steel wheels; axles, 2ins. diameter ; gauge of wheels, 2ft. 9ins. The frame of the bottom is 3ins. by 3ins. angle iron, carrying four 3ins. by ⅜in. side straps lined with $\frac{3}{16}$in. sheet iron. The top ring is beaded iron, 3ins. by ⅞in. When the tubs are loaded level they carry 20 cwt.; when pitched 6ins. higher than the top they will carry 26 cwt. At this colliery the coal is loaded into tubs by rake and pan, and the lumps stacked in by hand.

LLWYNYPIA COLLIERY.

GLAMORGAN COAL COMPANY.

AT this colliery they had just erected an improved Sheppard machine for washing very small dross, but the machine had only been started a few days before our visit, and had been stopped for alterations, the results of the first working not being satisfactory. The machine is a modified type of the Sheppard tank washing machine, with quickly pulsating plungers. We did not go into the details of this machine under the circumstances, but Mr Hood agreed to furnish us with a full detailed description, with the results, if it turn out a success.

The other system of coal washing here is the open trough system. The water with the very fine coal passes into settling ponds at the ends of the troughs, and, after being drained there, is pumped back to the top end of the troughs to be used over again. Otherwise, this system is the same as is used in a great many places, both in Wales and elsewhere, and requires no further description. The whole of the washed dross is used for coke-making.

EBBW VALE COLLIERIES.

WAEN LWYD PIT.

THE following is a description of a system of movable screens and general arrangement of the pithead here, and a drawing is shown on Plate XI. :—

The seams worked are as follows, viz. :—(1st) Elled seam—roof, strong shale ; coal, 3ft. 6ins. thick ; (2nd) Big vein—roof, strong shale ; falling, soft shale, 4ins. ; coal, 5ft. 6ins. thick ; (3rd) Three-quarters seam—roof, shale ; falling, soft shale, 4ins. ; coal, 3ft. 4ins. thick.

Pieces from the roof and pavement and the soft falling above the coals get mixed with the latter.

The pit is 85 fathoms in depth ; the output is about 1100 tons per day of 9½ hours' winding. The hutches are 4ft. 6ins. long, 3ft. broad, and 12ins. deep, and are heaped to contain an average load of 19 cwts. of coal and dross. About 30 per cent is dross through a 1in. screen. There are six screens arranged in pairs, so that each two deliver into a coal waggon. These are all on one line of rails, the dross waggons being on a second line. The pit-head is arranged as shown on Plate XI., with a pair of outside roads, along which the empty hutches are taken from the screens to the back of the pit by endless long-linked chains, to which upright bars are attached. These catch the axles of the hutches and propel them along at a slow rate to where the road turns towards the back of the pit, to which they run by gravity. From this point the endless chain passes under the floor back to the other end. The pit is 60 feet from the tip at the screens, and the above arrangements work well in the circumstances.

The feature of the screens at this colliery is that they fold down so as to prevent breakage of the coal, the principal screens going right down to the top of the waggons, as shown on the Plate by dotted lines. The tumblers, which are partly of plate iron, 3ft. 6ins. long, and partly of screen bars, 4ft. long, are held in a horizontal position by a pin at the side, which is worked by a crank from a tread. The principal screens, the bars of which are 16ft. long by 5ft. wide, are made with a curve near their lower end, where there is a plate 7ft. 8ins. by 5ft., on which the coals

are picked free of rubbish. These screens are hung on trunnions. On one side is a brake wheel and strap, 4ft. 9ins. diameter, on slackening which the screen tips up, and the coals are discharged into the waggon. The following is a description of how the work is performed. The hutch is run on to the tumbler and its door is opened by a short lever. The man then withdraws the pin by putting his foot on the tread, when the tumbler heels over by gravity, and the coals are emptied on the principal screen, the fall being broken by the swinging plate. The tumbler is brought back by the weight of the empty hutch and balance. The coals are then picked on the plate at the foot of the screen by two men. When this is done the whole screen is tipped up by lifting the brake handles, and the low end of the screen is brought down to the top of the waggon. When the coals are discharged it is brought back into position by its own gravity. About 250 tons a day over such a screen is found sufficient, with 4lbs. to 8lbs. of stones to be picked from each hutch of 19 cwts.

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SHEFFIELD, NOTTINGHAM, AND MANCHESTER DISTRICTS.

BARROW COLLIERY.

THIS Colliery is situated near Barnsley, and the present output is from 1200 to 1500 tons daily, but preparations are being made for a considerable increase.

The surface arrangements are very extensive and complete, and are carried out with great skill.

The coal worked is the well-known Silkstone seam. The produce is graded at the pithead into six kinds, the relative values being approximately as follows:—

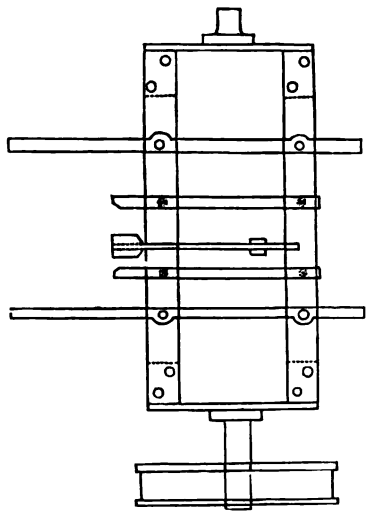
1. Lumps,		100
2. Gas coal,		85
3. Steam coal,		85
4. Nuts,		78
5. Peas,	Both taken to boilers or washer as required.	60
6. Smudge,		

Dry Cleaning.

The coal is filled underground with the ordinary close shovel and sent to bank as triping, and there prepared for market.

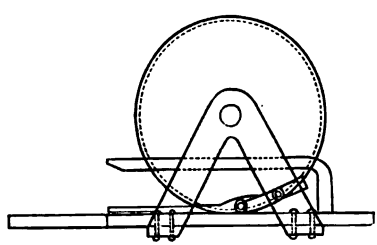
The hutches are made of wood and have close ends, the boxes being about 4ft. long, 3ft. wide, and 2ft. deep; capacity, 9 to 10 cwts; wheels, 8ins. diameter; with flanges to run on edge rails laid to a gauge of 24 inches.

The tumbler is of the backward tumbling kind, which turns the hutch upside down, as here shown, and delivers the



Tumbler—Plan.

coal on the top plate of the screen. At the bottom end of this plate, and at the top of the screen bars is a shutter or door, to which a boy constantly attends, his chief duty being to regulate the flow of coal down the screens.

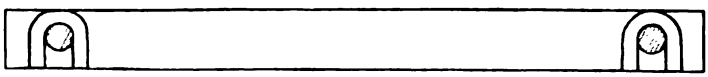


Tumbler—Elevation.

The general principles and arrangements of the screens are shewn on Plate XII. Referring thereto, *A* is the tumbler, *B*, B^1,

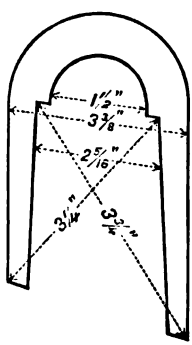
B^2, B^3, &c., are the several screens arranged all at the same inclination of about 15ins. per yard, one above the other, and only a few inches apart.

The top screen is fixed and formed of bars about 12ft. long, supported on round rods, the distances apart being regulated by washers of a horse shoe pattern, thus—



Screen Bar and Movable Washers.

This form enables the washers to be placed on and removed from the cross-bearers supporting the screen bars with facility, and the spaces between the bars varied at will with as little labour as possible.

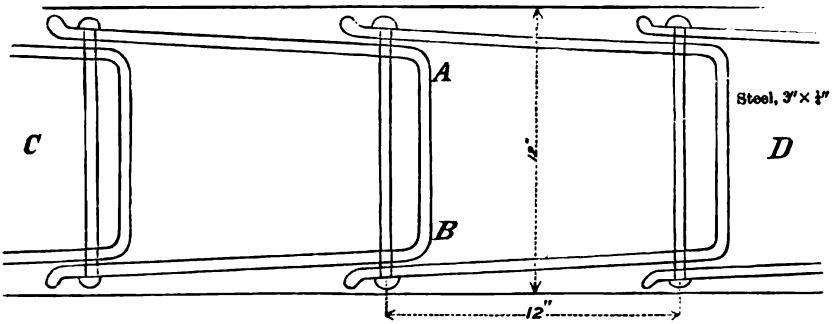


Washer.

The under screens B^1, B^2, &c., are riddles, varying in the mesh from ⅜in. to 1¾ins., and vibrating from 80 to 100 strokes per minute, each of which delivers the coal passing over it into shoots, discharging on travelling picking tables. The number of under screens or riddles corresponds with that of the grades of coal here prepared for the market.

The bottom riddle B^3 passes only gum, and delivers into a hopper, which empties itself into a cast-iron trough, about 12ins. wide, and in which moves a creeper that rakes the gum towards the stokehole of the colliery boilers.

The construction of this creeper is shown on the accompanying figure.



Creeper.

Two pitch chains carrying a cross piece, A B, work in a trough, C D. The motion of the whole is from a common shaft with belts.

The picking tables are endless bands of wire netting made by suitable mechanism to travel at a speed of 30 to 35 feet per minute. In some the meshes are closed with strips of hoop iron inserted so as to make practically a close sheet.

The picking tables are arranged one on each side of a line of rails, and at right angles thereto. See Plate XII. One travels towards the right, and the other to the left, both discharging on a trimming shoot, *C*, suspended above the railway waggon.

When tender coal has to be dealt with these trimming shoots are sometimes automatic balance plates, arranged so as to gently lower the coal into the waggon.

The outer ends of these travelling tables can be elevated so as to allow the coal to be delivered into tubs and then run out to the bing when stocking is necessary.

All screens and picking belts are started and stopped by levers and clutches as required, and are driven by belts from a main shaft.

The refuse consists of stones and shale got along with the coal, and is loaded into hutches and taken to the spoil bank. About 1·25 per cent. of dirt is taken out in the process of dry cleaning.

Wet Cleaning.

The washing machines are placed at a distance from the screens, and the dross is carried from the one to the other in railway waggons. These discharge it into a hopper, from which it is elevated and passed through a disintegrator to reduce it to a practically uniform size. Thereafter it is delivered into the conical hopper of a Robinson washer, the general arrangement of which is shown on Plate XIII.

This washer consists of a cone of plate iron or steel about $\frac{3}{8}$in. thick, in which revolves a vertical shaft carrying cross arms. The water under pressure flows in at the bottom and passes upward through the coal while it is being agitated, and the coal being lighter than the shale finds its way to the top of the hopper, while the shale or dirt works to the bottom. The coal and water are discharged at the top of the hopper on to a perforated plate, which shoots the coal into waggons for transport to the coke ovens. The water drains through the perforations and is collected into convenient tanks there and allowed to settle to be used again.

The dirt is discharged through a valve in the bottom into another waggon or hutch.

The greatest diameter of the cone of this washer is about 10 feet, and it is capable of treating from 24 to 28 tons per hour. The maximum capacity is 30 tons per hour.

The dirt taken out in washing is about 8 per cent. to 10 per cent. of the total weight of dross put into the washer, but we did not obtain any information as to the quantity of dirt in the dross before and after washing.

Two men are employed attending to the emptying of the waggons, and other two men to the engines and gearing.

The coal being reduced to a uniform size previous to washing, the Robinson machine gives fairly satisfactory results.

There are several settling tanks to collect the water and smudge which flow from the washer. These are of various dimensions. Their capacity is about 6500 cubic feet, and they are cleaned out weekly. After settling, the water is raised by a No. 10 pulsometer pump into the overhead tank for supplying the washer.

No record is kept of the quantity of water used.

It would serve no practical purpose to estimate the total cost of the several washing plants, as this depends on the position of the pits, the markets wherein the coal is disposed, and the completeness of the automatic arrangements carried out for moving the coal. These in every case will vary according to the idea and resources of the colliery proprietors. Besides, the several installations have all been got up tentatively, and alterations follow improvements; and, were any one of them re-erected, the structural arrangements would be different, because previous experience would be taken advantage of in working out the designs so as to minimise cost.

The cost for cleaning the dry coal, labour and repairs, is about 1½d per ton, and the cost of crushing and washing 2½d per ton.

ALDWARKE MAIN COLLIERY.

THIS colliery is near Sheffield, and puts out about 2200 to 2000 tons per day. The surface arrangements are most complete and effective, and the whole is arranged in such a manner as to carry out the work of coal sorting and cleaning at the least possible cost. Every effort is made to prevent waste.

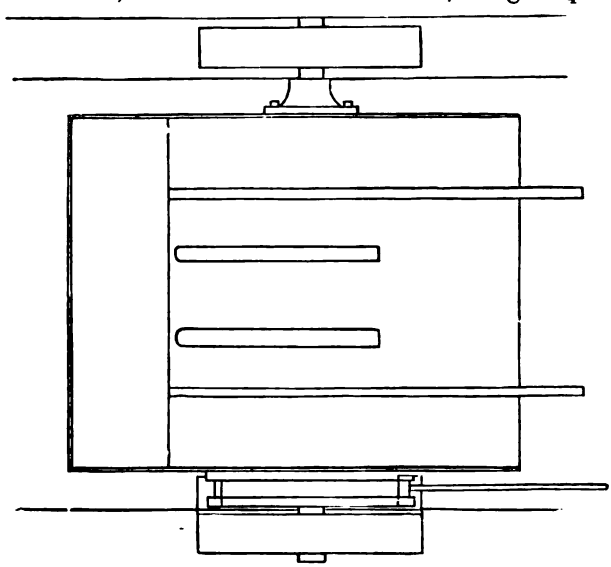
The Parkgate, or gas coal, and Barnsley, or steam coal, seams are worked, and the produce is classified as follows :—

1. Lumps—No. 1 gas,	60 per cent. of output.		
2. Nuts,			
3. Peas,			
4. Lumps and Nuts together, No. 2 gas,	75	,,	,,
5. Lumps, Nuts and Peas, No. 3 gas,	86	,,	,,
6. Smudge, used for coke-making.			

When there is not sufficient smudge to make the full quantity of coke required, peas are ground up to supplement the smudge.

Dry Cleaning.

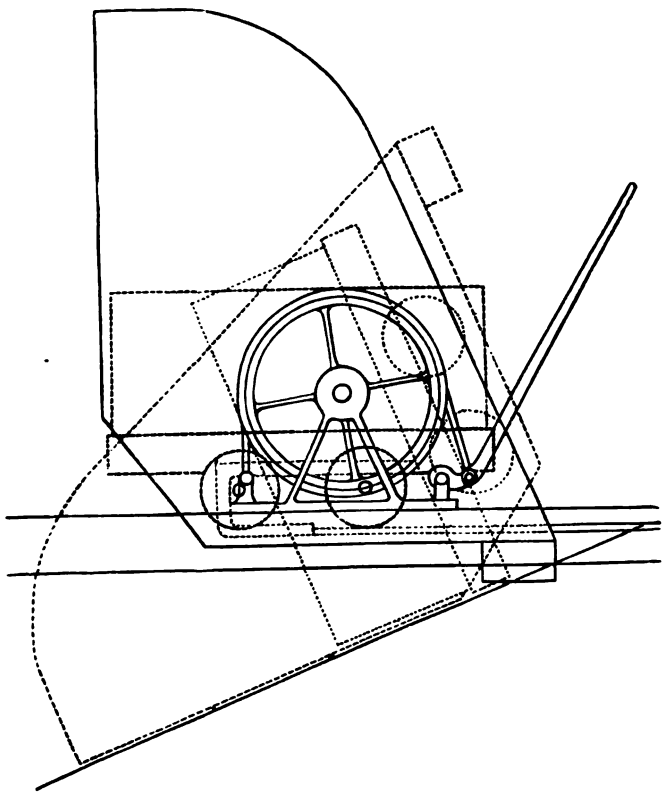
The hutches, which are made of wood, weigh 3¾ cwts.,



Rigg's Tumbler—Plan.

and carry 8 to 9 cwts. of coal. The dimensions are 3ft. 6ins

long, 2ft. 10ins. broad, and 2ft. deep, with wheels about 8 inches diameter, adapted to run on edge rails. All the hutches have close ends. The tumblers in use are those known as "Rigg's," as shown on the accompanying woodcuts. They tip forward and turn the hutch over, thus :—



Rigg's Tumbler—Side Elevation.

The general arrangement of the screens is shown on Plates XIV. and XV. Referring thereto, the several screens are indicated by the letters B^1, B^2, B^3, and the picking bands, by the letters C^1, C^2, C^3, the tippers being fixed at the point A. These tippers are fitted with a heavy hinged flap for regulating the flow of coal. No attendants are necessary for this purpose. But

in addition to these flaps, sometimes a heavy piece of iron or wood is suspended by chains from the top of a screen or shoot, B^1, and lies across the floor of it at about one-third of its length from the top. Further across the inner end of the picking table there is fixed a board K (Plate XIV.) adjustable vertically like a sluice. This sluice board effectually serves its purpose, the layer of coal delivered on the travelling belts being exceedingly regular. It will be seen that to each screen there is a corresponding picking table. The bands or tables are formed of plates about 14 inches broad, fixed at each end to endless chains working over polygonal drums. The bands are about 60 feet long, and travel at the rate of 40 to 50 feet per minute. At the delivery end of each band is an arrangement of short screens for removing any gum made on the tables.

The *modus operandi* is as follows:—Screen B, which is inclined at an angle of 18° has a riddle B^1 with mesh 1½ins. by ⅞ to 1¼ins. fixed over it and vibrated at 106 strokes per minute by an eccentric of 7ins. stroke. The riddle B^1 delivers the lump coal on the picking table C^1, and the dead shoot D delivers what passes through riddle B^1 of screen B on to B^2.

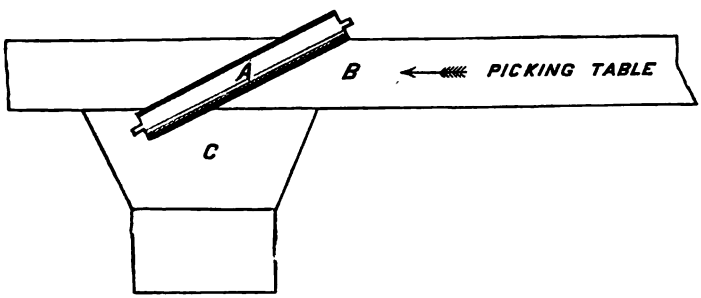
Screen B^2 is ¾in. mesh. What pass over it on to the picking table C^2 are nuts, what passes through it falls on to the screen B^3, the mesh of which is $\frac{3}{16}$in. What pass over B^3 on to the picking table C^3 are peas, what passes through B^3 is smudge, and it is delivered either into a waggon L^3 direct, or into a creeper which conveys it to an elevator in connection with the washing apparatus. Fine dross taken out by the short screens H and G^1 is conveyed by the lower or return side E^2 of creeper $x\ y$ to the waggon L^4.

These picking tables are fixed on a platform above the several lines of rails, and instead of being at right angles to the railway, as at Barrow, are parallel thereto. There is a line of rails corresponding to each grade of coal produced.

To facilitate the mixing of the different grades (as is done to produce No. 2 and 3 gas mixtures), by-pass doors F, forming the dead plate of screen H, are raised so as to direct the coal over screen, G^1, into the creeper E^1. The mode of operating is as follows:—A waggon L^1, is placed on the outer line of rails, on the right

and under the lump coal band C^1, into which is delivered the lump coal. The by-pass doors F, at the end of the nut or pea bands, or both, as the case may be, are raised, and nuts or peas, or both, are diverted into the creeper E^1 (instead of into waggons), which is travelling towards the right hand, and arranged to deliver these along with the lump coal into the waggon L^1; the gum being always taken out and carried back by the creeper E^2, to the waggon L^4. No balance plates are used at this colliery.

A convenient arrangement for delivering coal, from say the middle of a picking table into a shoot, may be here mentioned. It consists of a fluted roller working obliquely across the table, thus:



The roller A, is made to revolve, and is adjusted so as to work either the whole or a part of the coal from the band B, into the shoot C. These rollers can be fixed anywhere and in any number along the line of tables, and in certain cases are a very great convenience in sorting coal.

The screens and the three picking tables or bands above described, deal with 600 tons of coal in 8 hours. On the band C^2, which deals with nuts, or about 15 per cent. of the total output, 6 boys are employed. On band C^3, over which passes about 10 per cent. of the output in the shape of peas, 2 boys are employed. On band C^1, which deals with large coal, or about 60 per cent. of the output, 6 young men are employed.

The dirt picked out is about 5 per cent. of the gross output, and the dust or gum amounts to from 12 to 14 per cent. The refuse consists of stones and shale, and is conveyed to the spoil bank.

Wet Cleaning.

The general arrangement of this plant at Aldwarke Main Colliery is shown on Plate XVI. The coal, when separated from the bands or ribs of shale in the seam, is comparatively clean. Such coal as is intended for coke-making is conveyed from the screen in a waggon to the washing apparatus. It is tipped into a bunker and elevated on to a riddle. What passes over the riddle is dropped into a trough washer, and makes small washed pea nuts. What passes through the riddle goes into one of Qualter Hall & Coy.'s roller crushers, and is crushed fine. The crushed coal is delivered into a trough that carries it to the washing spouts for the coke ovens. All the coal is washed in troughs, section 16ins. by 9ins. These serve both to convey the coal from the pithead to the washing ground, and for washing as well. Their length is considerable, as the washing ground is at some distance from the pit, and in close proximity to the ovens. The washers proper are fitted with glass bottoms, and bars for catching the dirt are fixed across them at short intervals. The troughs are carried on the top of wooden bunkers, into which the washed coal is dropped and allowed to drain for 24 hours. Afterwards it is withdrawn from the bottom of the bunkers into waggons and conveyed to the coke ovens. About 180 tons are washed in 10 hours, and about 50 yards' length of double trough is considered ample for washing 100 tons of coal in 12 hours.

These cleaning troughs have a fall of 1½ins. per yard. The dirt taken out is about 12 per cent. of the unwashed coal. The dirt left in the washed coal is about 4 per cent. of its weight. The coke contains 6 to 7 per cent. of ash.

The settling tanks are three in number, each 48ft. × 20ft. × 7ft., and each holds about 40 tons of dirt. The water from the settling tanks is partly used over again and partly run to waste. It is

found that if the water is used too often the coke is deteriorated by an admixture of fine foreign matter. The dirt in the settling tanks is an impalpable powder containing about 30 per cent. of clay; the remainder is coal. This dirt is carefully dried and used at Atlas Works for foundry blacking. No filters are in use for purifying the water before it passes into the natural brook.

No record is kept of the quantity of water used, as there is abundance of water for the purpose pumped from the pits.

The cost of elevating, crushing, and washing is about 2¾d per ton of coal treated.

NUNNERY COLLIERY.

THIS colliery is on the outskirts of Sheffield, and the output is about 1200 tons per day. The arrangements on the surface are designed to serve the same purpose as those at Barrow and Aldwarke Main Collieries, but are not so extensive. The general arrangements are shown on Plate XVII. The seams now being worked are the Parkgate and the Silkstone seams, and the produce is subdivided as at the collieries previously described.

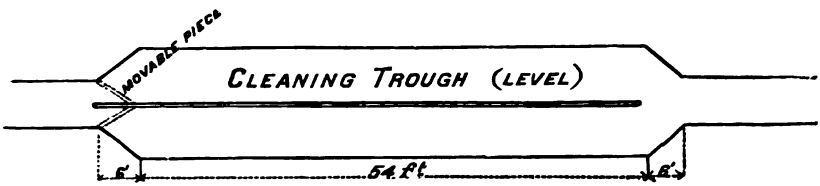
Dry Cleaning.

The coal is filled underground with ordinary shovels and sent to the bank as triping, as much dirt being kept out underground as possible. The hutches used here are similar to those at Barrow Colliery. All the tipping machines in use are the kind known as Rigg's, and tip forward with a balanced door to prevent breakage. The cleaning arrangements for the coal loaded into waggons consist of three vibrating screens, to each of which is fitted a travelling belt or picking table, the dimensions and working speeds being as follows:—The shaking screens are 22ft. 6ins. by 5ft., with $\frac{13}{16}$in. mesh, and an inclination of 1 in 4; the main belts are 35ft. by 4ft., and travel at a speed of 40ft. per minute; the smudge creeper is 50ft. by 10ins., with a speed of 100ft. per minute; the nut travelling belt is 62ft. long and 4ft. wide, and has a speed of 40ft. per minute; the nut screens are 4 feet long and 5ft. wide, $\frac{3}{8}$in. mesh; the revolving screen is 9ft. long and 2ft. 6ins. diameter, $\frac{1}{2}$in. mesh. The screens are similar to those at Aldwarke Main, but are not on such a complete or extensive scale. About 2 per cent. of dirt is taken out of coal so treated. This colliery has a large local sale; but the screens over which this coal passes do not call for special comment. The refuse from the picking tables is thrown into bunkers, with a trap door in the bottom, delivering into hutches, which are conveyed by a moving rope to the spoil bank, the dirt being brought below the railway.

Wet Cleaning.

The portion of the output washed is the smudge. It is not crushed previous to washing. The washing is done by the trough

system, and is similar to that at Aldwarke Main. The dirt taken out is removed from the troughs by workmen and shovelled into hutches. The cleaned coal is conveyed by the water about half-a-mile further to the coke ovens. About 220 tons are washed daily in 14 hours. The inclination of the troughs from the feed hopper to the washer is 2ins. per yard. The greater part of the remaining length of half-a-mile is inclined 1½ins. per yard. Part of it is flat, and catches the escaped dirt from the washing places, amounting to about four tons daily, and this is flushed out at night. The following is a sketch of the washer :—



Trough Washer.

About 10 per cent. of dirt is taken out by the washing. Settling tanks are used, the main feature of which is that they are *above* the coke ovens, and are surrounded by a narrow channel through which the overflow passes, dropping finer and finer silt as it goes. The quantity of water used is considerable, there being a large volume pumped from the pits. None of it is used over again, and no record is kept of the quantity used per ton of coal washed, but about 200 gallons per minute is used.

The cost of dry cleaning is about 3d per ton for labour and repairs. The cost of wet cleaning is 1·40d per ton.

LINBY, ANNESLEY, AND NEWSTEAD COLLIERIES.

THESE collieries are near Nottingham, and put out a class of coal very different from that raised in the vicinity of Barnsley and Sheffield. It is much stronger, works rounder, and indeed is not unlike the Splint seam of the Hamilton district.

There is, as yet, only the Top Hard seam worked in this locality, and it is said to correspond in position to the Barnsley seam of Yorkshire.

The produce is sent to widely different markets: to London for house coal, to blast furnaces in the neighbourhood, local household consumption, steam ploughing, and to the Cheshire salt mines. The output is graded as follows:—

1. Best bright household, -	value May, 1889,	6s 6d	per ton,	free on rail.
2. Bright screened cobbles, -	,,	,,	5s 0d	,,	,,
3. Blast furnace or steam coal,	,,	,,	6s 0d	,,	,,
4. Hard steam or local household,	,,	,,	6s 0d	,,	,,
5. Picked hard steam, - -	,,	,,	6s 0d	,,	,,
6. Nuts, - - - -	,,	,,	6s 0d	,,	,,
7. Slack, - - - -	,,	,,	3s 0d	,,	,,
8. Smethum, - - -	,,	,,	1s 6d	,,	,,

Blast furnace coal and the several kinds of steam coal form about 60 per cent. of the produce. Bright household screened cobbles, nuts, and slack, or dross, amount to about 30 per cent., and smethum, or gum, about 10 per cent. None of this coal is suitable for coke making.

The coal is all hand-picked underground, and no dross is put out. That left below is about 10 per cent. of the total produce of the seam.

The hutches are all made of wood, and the box is 4ft. long, 3ft. broad, and 2ft. deep, and holds about 11 cwts. They have no door; but, instead, the longer pieces of round coal are built into the front lengthwise, and on the bottom of the hutch at the front edge is nailed a cleat, thus,

All run on edge rails, 26ins. gauge.

All the tippers throw the coal forward into a shoot, delivering

on the picking table, which runs parallel to and between two trains of waggons about to be loaded. See Plate XVIII. This shoot has the bottom formed sometimes of screen bars, and sometimes of dead plates. No special provision is made for protecting coal from breakage while being tipped, as here it is not required.

The screens and picking tables now about to be described are gradually superseding all older arrangements in use in this district.

The picking tables or belts are from 3ft. 6ins. to 4ft. wide, and travel at a speed of about 30 to 35 feet per minute. They are usually about from 220 to 250 feet in length, *i.e.*, the length of 12 to 14 waggons alongside of the table.

They are made of iron plates, 14ins. broad by $\frac{3}{16}$in. thick, fixed on wrought iron link chains, and are put in motion by polygonal drums. They travel in wooden frames formed of battens, 6ins. by 2½ins., the inner sides of which are covered with steel plates, about No. 12 B.W.G., where exposed to friction of the coal. The belt is supported in the frame on rollers.

Two men are allotted to the filling of each waggon next to the shoot delivering on the picking table. As the coal advances towards the far end of the tables, and becomes less round, the number is gradually increased to 4, 6, or 8 men and boys per waggon. They are arranged so that the whole of the waggons alongside the table at one time are loaded with the different kinds of coal as nearly simultaneously as possible. The men do not move from one waggon to another, but the attention of each is specially concentrated on the special class of coal he is expected to remove from the belt while in motion. If one waggon be loaded before another, the defect in the arrangement of the men is quickly detected, and the remedy applied.

All the pieces thus picked off are separately and most carefully packed into trucks, and the result is a very fine appearance, a great attraction to customers, and a large saving in the amount of dross produced by friction on a long railway journey.

The picking bands deliver all coal left on them at the far end, by means of a balance plate (see Plate XVIII.), to an elevator the full width of the bands. It consists of a series of troughs, about 14 inches wide by 6 inches deep, inclined about 35 degrees to the

horizontal plane. These, in turn, deliver on a screen; the lump coal passing over the screen is dropped by a balance plate into a waggon, and the dross going through the screen falls into a different waggon on another line of rails, the arrangement being similar to the arrangement of screen in common use in Scotland.

The picking table above described is driven by an engine having a cylinder 14ins. diameter by 30ins. stroke, geared about 22 to 1. Steam pressure, 50 to 60 lbs. per sq. inch.

The screens are driven by a separate engine, cylinder about 6ins. diameter by 14ins. stroke. They have bars about 5ft. long, are inclined 1 in 4, and are vibrated by eccentrics of about 8 ins. stroke, 115 times per minute.

The apparatus above described is now dealing with 700 tons per day of 8½ hours, but, it is said, could overtake 1200 tons in the same time.

The cost of sorting coal in the manner above described, not including depreciation, is from 2½d to 3d per ton, depending on the quantity of dirt in the coal. This cost is from 1d to 2d less for wages than was paid under the former system; but besides this saving there is a considerable improvement in the gross value of the output, and in the facilities for loading into waggons, and, at some collieries, a saving in capital outlays.

No coal is washed in this locality.

CLIFTON COLLIERY.

THESE collieries are near Manchester, and put out coal from three seams. The whole output is prepared for and sold within a radius of 20 to 30 miles, chiefly as household coal, and as steam coal for manufacturers' purposes. The coal "works small," and the gross produce is in appearance not unlike that raised at Barrow, Aldwarke Main, and Nunnery Collieries.

The seams worked here are known locally as the Trencherbone, the Doe, and the Quarter seams. The output is graded into thirteen kinds, as follows :—

1. Manchester best,	value May, 1889,	free on canal or rail,			10s	per ton
2. Manchester best,	,,	,,		,,	9s	,,
3. Doe best, - -	,,	,,		,,	10s	,,
4. Doe tops, - -	,,	,,		,,	8s 6d	,,
5. Quarter, - -	,,	,,		,,	10s	,,
6. Roughs—produce from all together,				,,	6s 6d	,,
7. Riddled, - - - - - - - -				,,	8s	,,

8. Washed slack, No. 1 quality, value May, 1889, free on canal or rail, 4s per ton.,
9. Washed slack, No. 2 quality, value May, 1889, free on canal or rail, 4s 6d per ton.
10. Washed slack, No. 3 quality, value May, 1889, free on canal or rail, 4s 10d per ton.
11. Washed slack, No. 4 quality, value May, 1889, free on canal or rail, 6s per ton.
12. Burgie—not sold—*i.e.*, the coal is put out from the pit after the hand filled coal is removed.
13. Slack unwashed, value May, 1889, free on canal or rail, 3s 6d to 4s 6d per ton.

This coal is suitable for coking, but up to this time a market has been found for it in the raw state, so that here none is coked. It contains a good deal of pyrites.

Dry Cleaning.

The coal is hand-picked underground, and is run from the pit cage direct into railway waggons or canal boats, where any inferior piece observed is picked out. What remains after the hand-picked coal is removed is known as Burgie. This is filled with a close shovel underground, raised to the pit bank,

and tumbled into a screen with an inclination 1 in 1·8 (see Plate XIX.) What passes through the screen is conveyed by creepers and elevators into a Coppee washing machine.

What passes over the screen is delivered upon a picking table rising from the bottom of the fore-mentioned screen, at an inclination of 1 in 2·5 to a scaffold, having a sufficient elevation to enable the coal to be tipped into railway waggons.

This picking table is a wire work band similar to that in use at Barrow Colliery. It is about 30 feet long, and 4 feet broad, and moves at a speed of about 15 feet per minute. The coal, in moving upward on the table, is nearly all picked off by hand, all the pieces pertaining to one grade being thrown into a corresponding hutch.

What passes over the table, and which may be said to correspond to nuts, is dropped into a hutch.

The respective hutches are tipped from the pithead scaffold into corresponding waggons to be despatched to the market. For the arrangement of railway lines and tippers, see Plate XIX.

Two tables such as described can deal with 350 to 400 tons of burgie per day, at a cost of from 3d to 4d per ton.

The hutches are of wood, with close ends, and are 3ft. 6ins. long, 3ft. broad, and 1ft. 8ins. deep—contents, 7 cwts. The wheels are 10ins. diameter, to run on edge rails, laid to 22ins. gauge.

Both back-tumbling and fore-tumbling machines are in use, but no special precautions are taken in connection therewith for lessening the breakage of coal; but at one of the collieries situated on the canal a series of balance plates are being fitted up with that object in view.

Wet Cleaning.

At this colliery the Coppee and Robinson washers are used.

The Coppee machine has been in use about 18 months, and is intended to deal with about 400 tons daily. The coal to be washed contains 15 per cent to 18 per cent. of dirt, and the cost of washing (all working charges included), is about 6d to 7d per ton.

The waste water passes into settling ponds having a total capacity of 450 cubic yards. They are cleaned out once in two weeks by washing out through a sluice.

Difficulty is experienced in effectually dealing with the dirty waste water, but this might be overcome by filtering through the spoilbanks at the pitmouth adjoining.

The Robinson washers are only lately put in operation, and the whole arrangements in connection therewith are not yet completed, therefore no comparison could be made of the efficiency and cost of washing by the two types of machines in use at these collieries.

The hoppers of the Robinson machines have a maximum diameter of 6ft. The nominal capacity is 150 tons per day. The actual capacity is found to be 100 tons. The coal to be washed is separated into two sizes, and the peas are delivered and washed in one machine, the dross in the other. The washed peas are screened by a revolving riddle, and the pea-nuts thus separated are hand picked while being dropped into a bunker provided with bottom doors by which these nuts are loaded into hutches for transport to the canal.

A special feature here requiring notice is that the water, in flowing from the machine previous to entering the settling tank, is allowed to deposit part of the contained dirt in settling troughs.

The idea in all these arrangements seems to be not so much to get a greater profit out of the coal in consequence of improving the quality by washing, as that they are now a necessity to meet the demands of consumers.

STATEMENTS CONTRASTING THE PRACTICE AT THE SEVERAL COLLIERIES IN THE SHEFFIELD, NOTTINGHAM, AND MANCHESTER DISTRICTS.

I.—Dry Cleaning.

Name.	Speed per minute of Picking Bands.	Number of belts.	Total length of bands.	Total length of band available for operating on	Capacity.	Vibration of screens per minute.	Inclination.
	Feet.		Feet.	Feet.			
Barrow . .	30 to 35	...	...	...	1200 to 1500 tons daily	80 to 100	1 in 2·4
Aldwarke Main.	40 to 50	3	180	180	600 tons in 8 hours	106	1 in 3
Nunnery Main .	60	3	120	120	...	...	1 in 4
Do. Nut .	40	1	62	60	...	...	1 in 4
Annesley . .	30 to 35	1	250	250	700 tons in 8½ hours	115	1 in 4
Clifton . .	15	2	60	10	350 to 400 tons per day of 10 h.	All fixed	1 in 1·8

II.—Wet Cleaning.

Name.	Type of machine.	Nominal capacity per day of 10 hours.	Actual capacity per day of 10 hours.	Dirt in coal.	Taken out.	Left in.	Smudge Tanks.	Settling Ponds.	Tank Capacity per ton washed per hour.	
				Per Cent.	Per Cent.	Per Cent.	Capacity.	Capacity.	Smudge. *	Settling. *
		Tons.	Tons.				Cub. Ft.		Cub. Ft.	Cub. Ft.
Barrow .	Robinson	300	240 to 280	...	8 to 10	4	6,500	21,640	2·17	7·76
Aldwarke	Trough	...	180	...	12	4	20,115	Nil	11·27	Nil
Nunnery .	Do.	...	220	...	10	...	5,000	16,000	...	...
Clifton .	Coppee	400	300	...	15 to 18	...	12,150	...	3·04	...

* These are calculated on maximum capacity of the apparatus for want of more reliable data.

III.—Trough Washing.

Name.	Dimension of Double Trough Washer.	Washing capacity.	Inclination of Troughs.	Dirt removed Per Cent.	Dirt left in Per Cent.	Remarks.
Aldwarke Main	50 yards, 16 by 9	150 tons in 12 hours	1½ins. per yard Washer same inclination	12	4	Crushed
Nunnery . .	36 yards, 16 by 9	220 tons in 10 hours	From coal hopper to troughs 2ins. per yard Washer level	10	...	Smudge and peas not crushed

IV.—Hutches.

Name.	Box. Length.	Box. Br'dth.	Box. Depth.	Weight.	Capacity.	Dia. of Wheels.	Gauge.	Wheels.	Doors.	Ends.
	Ft. In.	Ft. In.	Ft. In.		Cwts.	Ins.	Ins.			
Barrow .	4 0	3 0	2 0	...	9 to 10	8	24	Flange	None	Fast
Aldwarke .	3 6	2 10	2 0	3¾	8 to 9	8	...	Do.	Do.	Do.
Nunnery .	4 0	3 0	2 0	...	9 to 10	10½	28	Do.	Do.	Do.
Annesley .	4 0	3 0	2 0	...	11	...	26	Do.	Do.	Open
Clifton .	3 6	3 0	1 8	...	7	8	22	Do.	Do.	Fast

Note.—All are made of wood.

V.—Costs (Labour and Repairs only), Per Ton of Coal.

Name.	Dry Cleaning.	Wet Cleaning.	Type of Washer.	Condition of Coal previous to washing.
Barrow . .	1½d	2½d	Robinson	Crushed
Aldwarke Main	...	2¾d	Trough	Do.
Nunnery. .	3d	1·40d	Do.	Not crushed
Annesley .	2½d to 3d	No cleaning here	...	...
Clifton . .	3d to 4d	6d to 7d	Coppee	Not crushed*

* Note.—This machine is not yet in complete effective working.

CUMBERLAND AND NEWCASTLE DISTRICTS.

FLIMBY COLLIERY, NEAR MARYPORT, CUMBERLAND.

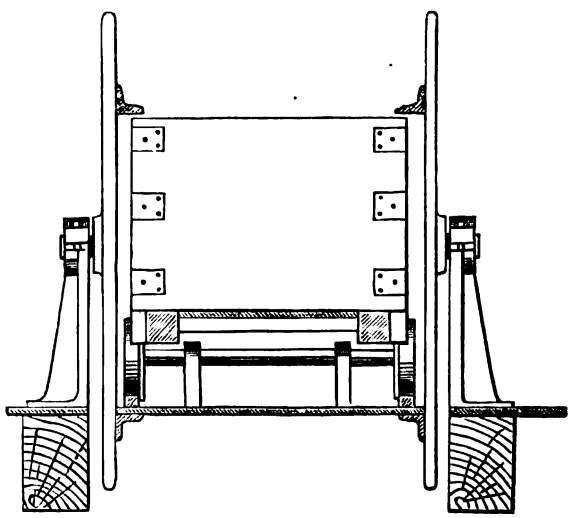
WATERGATE PIT.

There are four seams of coal worked in this pit, viz. :—the Ten Quarter seam, the Rattle Band seam, the Metal Band seam, and the Cannel Band seam. The first-mentioned is a house coal, the dross below ½in. being used for steam raising, while the other three seams are all coking coals, the round coal being used for steam navigation purposes, furnaces, and locomotives, and the dross crushed and coked.

The coal is all filled underground with shovels as triping.

The hutches are 3ft. 9ins. long, 3ft. 3ins. wide, and 1ft. 9ins. deep inside, the wheels being 10ins. diameter on the tread, and 16ins. between centres, with a gauge of 24ins. The hutches have no doors. The roads are all laid with steel bridge rails.

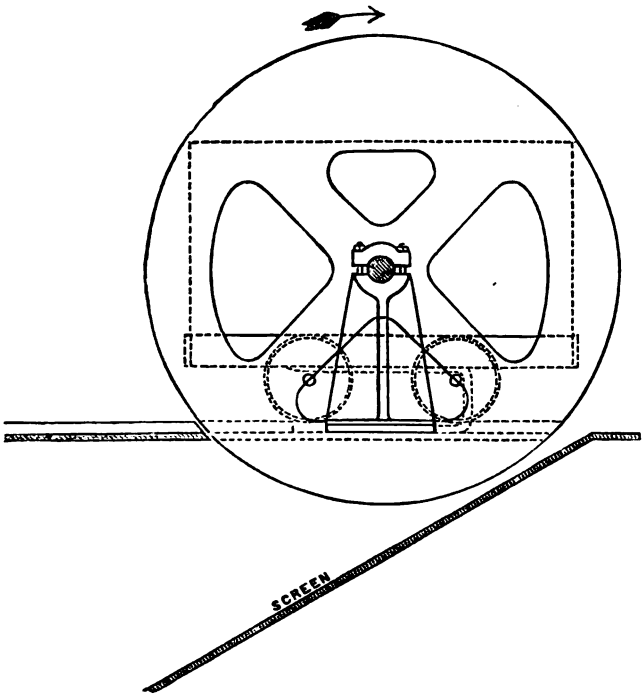
The coal is tipped on to the screens by Cook's tumblers, as here shewn, which invert the hutches, and the screens are all back



Cook's Tumbler—End Elevation.

screens, in order to reduce the distance which the coal has to fall.

The screening arrangements consist of two common screens and one jigger screen. One of the common screens is used for the



Cook's Tumbler—Side Elevation.

house coal, and the other for testing the amount of dirt in the coking coal hutches for "fining" purposes (*i.e.*, for imposing a penalty on the miners for sending up dirt with the coal), while the jigger screen is entirely used for the coking coals.

The scale of fines for dirt in the house coal is as follows :—

For	7lbs.,	- - - -	deduct 3 cwts.
,,	14lbs.,	- - - -	,, 6 cwts.
,,	21lbs.,	- - - -	,, 9 cwts.
,,	28lbs.,	- - - -	,, the whole hutch ;

while in the coking coal, in some cases the hutch is deducted for 7lbs. of dirt where there is little dirt in the seam.

The common screens are 5ft. 6ins. wide, with 6ft. of plate at the top, and 15ft. of bars, inclined 1 in 1·60. There is also a

landing, 6ft. long, composed of bars, on which the dirt is picked, and from which the round coal is shovelled into the waggon. The bars of these screens are cast in gratings, 3ft. long and 5ft. 6ins. wide, with a transverse rib across the centre. They are ½in. apart, ½in. wide at the top, ¼in. wide at the bottom, and 1¾in. deep.

The output of house coal is about 40 tons per day, and it is hand picked by five women, who also attend to a fines screen when a hutch is being tested.

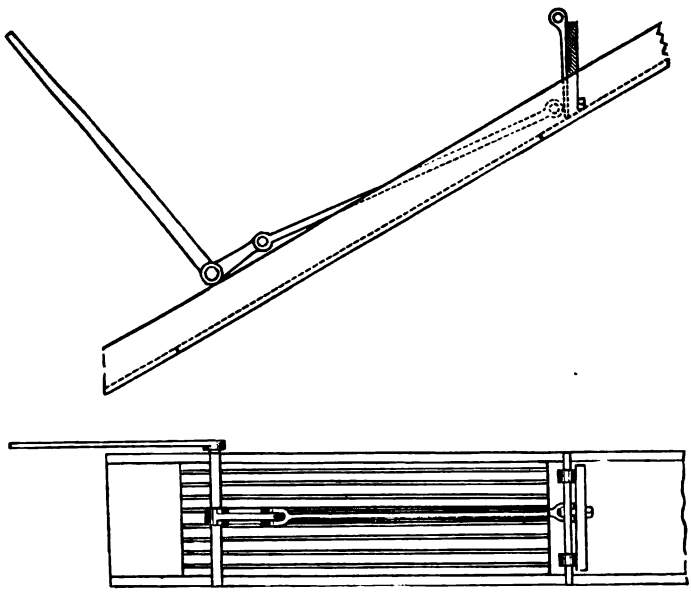
Assuming men to be paid 2s 8d per shift, women 1s 6d, and boys 1s 4d, and the quantity of dirt to be about 1 ton per day, the cost of picking 50 tons triping (10 tons at fines screen) or 35 tons round coal would be—

5 women, @ 1s 6d per shift, - - - - -	£0	7	6
Removing 1 ton dirt to the sea, @ 4d per ton, - -	0	0	4
Total wages, cost for 35 tons round coal, - - -	£0	7	10

which is at the rate of 2·68d per ton of round coal picked.

Plate XX. shows the arrangements for screening and picking the coking coal, and washing the dross. These consist of a jigger screen, a revolving table, and a Trough washing machine. The jigging screen is 14ft. long by 8ft. wide, and has an inclination of 1 in 5. It has a stroke of 4½ins., and makes 90 strokes per minute, deriving its motion from cranks on a transverse shaft driven by spur gearing from the crank shaft of a small horizontal engine. The jigger has steel bars 12ft. long and ½in. apart, and of the same section as those in the common screens. It is hung by four chains, which are said to have an advantage over rods in giving a slight hitch every stroke, but this hitch is so slight as to be imperceptible. The jigger receives the coal from two of Cook's tumblers, which are placed side by side, and each of the screens is fitted with a "kepper" at the top of the bars to regulate the descent of the coal on to the screen. This kepper is in use at nearly all the collieries visited, and the best form is here shown. When the kepper is shut the crank and connecting rod are in a straight line, so that no pressure of coal will open it, while the slightest pressure on the lever

is sufficient to do so. These keppers are of great use in regulating the supply of coal to the jigger, or to the bars of



Screen and Kepper.

the screen, so as to prevent overcrowding, and also for keeping hutches separate for fining purposes, there being room for a hutch or two above the kepper. Of course, the screen must be so steep that the coal will start to run down after being stopped.

The jigger lands the coal on the revolving table, from which, after being picked, it is discharged into the waggon. This table is 10ft. in diameter, with a space in the centre 6ft. 8ins. in diameter, leaving a ledge 20ins. broad all round on which the dirt is picked. The table revolves 3 times per minute, and the whole output of 350 tons triping, yielding 250 tons of round coal, is picked by 6 women who throw all dirt, and pieces of coal and dirt sticking together, down through the hole in the middle of the table, whence it passes by a shoot to a small platform, where it is further picked by 3 women, who break

up the coaly pieces and fill the whole of the dirt into hutches, in which it is conveyed to the sea. About 9 tons of dirt are picked at this table per day, so that the cost of picking 250 tons will be:

9 women @ 1s 6d per shift, - - - -	£0	13	6
1 boy working engine and regulator @ 1s 4d. -	0	1	4
Removing 9 tons dirt, @ 3d per ton, - -	0	2	3
Total wages cost for picking 250 tons, - -	0	17	1

which is at the rate of 0·82d per ton of round coal picked.

Treatment of Dross.

The house coal dross is sold as it comes from the screen without further treatment; and the dross from the coking coal is, as already stated, washed, crushed, and coked. The system of washing adopted here is the Trough system, as shown on Plate XX. The dross falls directly from the screen into a trough, along which a stream of water is passing, by which it is carried down to the washing trough. At the point where the dross first meets the water, the trough or rhone is divided into two by a longitudinal partition extending down to within an inch or two of the bottom. This always leaves a clean water-way on one side, and so prevents flooding in the event of an extra rush of dross, while, at the same time, it causes the dross to become thoroughly saturated as it is washed away from the tail. The inclination of this part of the rhone is also steeper than the washer proper, so as to carry both dirt and dross down to the upper end of the washer. The washing machine consists of two parallel rhones, each 150ft. long by 17in. wide and 13in. deep, lying at an inclination of 1 in 36. These rhones are used alternately, one washing while the other is being cleaned. The velocity of the water is about 300 feet per minute, and the quantity used is said to be about 400 gallons per minute for 100 tons per day of 10 hours. As the current passes along, the larger and heavier pieces of dirt are deposited near the head of the rhone, while the coal and lighter pieces of dirt are carried further down. To assist in settling the small pieces of dirt, there are two stoppers about 2in. deep, one at the foot of the rhone and one about 20 feet further up. While the washing is going on, the

attendants occasionally stir up the dirt which has settled, so as to relieve any pieces of coal which may have become covered. When the dirt begins to show through the coal in the trough, the water is turned into the other one, and the dirt is shovelled out into hutches which stand alongside. The coal is washed directly into a large wooden box, from which it is elevated to the top of the waggon by a bucket elevator driven by a 6ft. water-wheel worked by the overflow water from the wooden box. There are one man and two boys in attendance on the washing machine. In wet weather the water from the pit is sufficient, but in dry weather the water is pumped up by a 3ft. centrifugal pump running at 250 revolutions, and used over again. The cost for washing 100 tons is as follows:—

One man, at 2s 8d per shift, - - - -	£0	2	8
Two boys, at 1s 4d „ - - - -	0	2	8
Removing about 18 tons of dirt, at 3d per ton,	0	4	6
Total wages cost for 100 tons, - - - -	£0	9	10

which is at the rate of 1·18d per ton of dross washed.
The washed dross is taken in waggons to the ovens, where it is crushed in a 4ft. 6in. Carr's disintegrator before being coked.

ROBIN HOOD PIT.

At the Robin Hood pit, a washing machine by Bell & Ramsay is in course of erection. The whole arrangements as proposed are shown on Plate XXI. The coal will be tipped on a jigger screen, from which the dirt will be picked and the coal landed directly into the waggon, while the dross will fall into a pit, from which it will be elevated to the washer. The washer is essentially a trough washer, with the addition of mechanical stirrers to help to float the coal, and so save water, and an almost automatic arrangement for cleaning out the dirt. Each rhone is hinged at the upper end, and has a shaft running along the whole length. This shaft is hung independently of the rhone, and is provided with stirrers, as shown in Plate XXI., Fig. 6, which have a transverse oscillating motion. There are also stoppers distributed

along the length of the rhone, some being fixed to the frame-work near the low end and others near the top end, being movable up and down by means of levers. For catching the fine gum floating with the water, there are one or two scum plates fixed to the rhone. These stoppers and scum plates are shown on Plate XXI., Figs. 4 and 5. When the rhone is to be cleaned, the lower end is lowered clear of all the stirrers and fixed stoppers, and the movable stoppers are raised so as to allow the rush of water to carry off the whole of the dirt to a hutch placed to receive it. See Plate XXI., Fig. 3.

ST. HELENS COLLIERY, SIDDICK JUNCTION, CUMBERLAND.

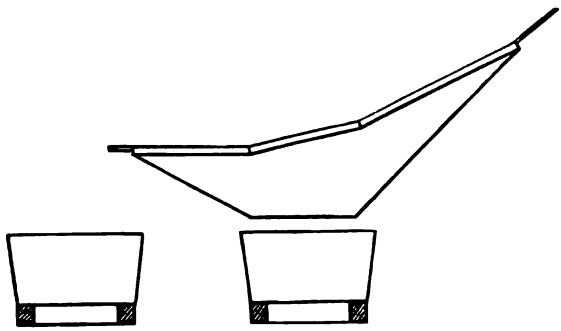
THE coals wrought here are non-coking, the round coal above ⅜in. being used for steam and locomotive purposes principally, while the dross is washed and sold for factory purposes.

The colliers fill all the output with shovels as triping.

The hutches are 3ft. 8ins. long, by 3ft. 2ins. wide, and 24ins. deep inside, and are filled only to the mouth. The hutch wheels are 12in. diameter on the tread, and 16in. between centres, with a gauge of 24in. The hutches are tipped by means of Cook's tumbler.

There are seven common screens, which are seldom used, one only being regularly used as a fines screen for examining hutches for dirt in order to make deductions. These screens are all placed side by side, and deliver the coal and dross into waggons on one coal and one dross road. These common screens are

arranged as shown on the accompanying figure. The coal is discharged from the tumbler into a shoot, and thence to the



bars, which are 21ft. long in three sections. The shoot is about 1 in 1½, and the screens are 1 in 2 for 9ft., 1 in 3·20 for 6ft., and level for 6ft., the latter portion forming a table on which the coal lies till the dirt is picked out, after which it is shovelled into the waggon. Each screen is provided with a kepper at the top of the bars, on the same principle as those at Flimby, by means of which the velocity of the coal can be regulated and each hutch kept separate if desired. The bars are ⅜ins. apart, and are ½in. wide at the top, the section being as here shown.

The common screens have been superseded by one set of jigging screens, shown in Plate XXII., which disposes of the whole output of fully 300 tons per day, with the exception of the fines hutches already mentioned. The jigging screen consist of two jiggers, each 12ft. long and 5ft. wide, having bars 7ft. 6ins. long and ⅜ins. apart, similar in section to those used in the common screens. The jiggers have an inclination of 1 in 4·36, and move backwards and forwards alternately, at the rate of 73 strokes per minute, with a 4½in. stroke. Each jigger is suspended from the

beams above by four rods, with adjusting screws, and the motion is derived from a small horizontal engine by means of cranks and wypers, driven by a single eccentric. While the coal is travelling down the screen, the dirt is picked out by 10 women and two boys, who are ranged along both sides of the screen and across the end, above the top of the coal waggon. The quantity thus picked is about 210 tons per day, including round, clean coal or bests, inferior coal or seconds, and dirt, the relative proportions of which are annexed. The coal and dirt picked out is thrown on a platform behind the pickers, from which it is filled into waggons at the end of the shift.

The following table shows the sub-division of the output into the various classes :—

Best,	63·00	per cent.
Seconds (inferior coal picked from table),	2·85	,,
Washed small (between ¼in. and ⅜in.),	15·68	,,
Washed duff (below ¼in.),	8·39	,,
Washed dirt,	4·32	,,
Dry small (below ⅜in.),	1·73	,,
Lumps dirt picked from jigger,	3·92	,,
Fine dirt (from fine screen,)	0·20	,,
Total,	100·09	

For a total output of 300 tons, the quantity of round coal and dirt picked would be about 210 tons, and the cost as follows :—

10 women, at 1s 6d per shift,	£0	15	0
2 boys, at 1s 4d ,,	0	2	8
1 boy at "kepper," at 1s 4d per shift,	0	1	4
Removing 12·36 tons dirt, at 3½d per ton,	0	3	7¼
Total wages cost for 210 tons,	£1	2	7¼

which is at the rate of 1·29d per ton of round coal picked.

The most of the dross is washed in a Sheppard washing machine, only a small quantity being sent away unwashed. The washing machine is situated below the screens, the dross waggons being run down and emptied into a pit from which the dross is raised by an elevator into the tanks. The machine has three tanks, each about 6ft. by 3ft., the total washing capacity being 200 tons per day, while the quantity being washed at present is

only about 90 tons per day. The dross is not sized before washing, but after being washed it is raised by an elevator to the top of a shoot with a barred bottom, which allows the duff or small to pass through into one waggon along with the waste, while the nuts pass on down the shoot into a separate waggon. The bottom of the shoot consists of a screen with bars ¼in. apart. The dirt from the washing machine is elevated and tipped into hutches, in which it is drawn to the sea and emptied, the distance being less than a quarter of a mile. In connection with the washing machine the following persons are employed, viz. :—One man looking after dross elevator, one man looking after dirt valves, &c., and the persons necessary for the disposal of the dirt. The cost for washing about 85 tons would thus be :—

2 men, at 2s 8d per shift, - - - - -	£0	5	4
Removing 12·96 tons dirt, at 2d per ton, - -	0	2	2
Total wages for 85 tons, - - -	£0	7	6

which is at the rate of 1·05d per ton of dross washed.

The water is allowed to run directly to the sea without any attempt at settling, but the quantity of fine coal lost is not great.

The usual form of Sheppard washing machine is shown on Plate XXIII., fig. 1, being a general view of the machine and elevators, and fig. 2 showing the construction and mode of operation of the washer.

The water is agitated by means of the piston and cylinder *E*, driven from the crank shaft of an engine. The dross falls into the tank at *A*, and, as the agitation proceeds, the dirt gravitates to the inclined bottom of that division, and, finding its way out at *C*, falls into the principal division of the tank, at the bottom of which is a screw to convey the dirt to the elevator, where it is raised to the discharge spout.

The washed dross passing into the space *B* is swept by the revolving brush *H*, and the larger pieces fall over the shoot into waggons, while the smaller particles pass through the perforated plate under the brush, and fall into the tank *D*. A screw at the bottom of this tank passes it on to an elevator, by which it is raised to a convenient height to be loaded. The arrows on fig. 2 indicate the direction of flow of the water in the machine.

MORESBY COLLIERY, NEAR WHITEHAVEN, CUMBERLAND

WAULKMILL PIT.

THE coal worked at this colliery is a good coking coal, the round coal being used for furnaces, locomotives, and steam navigation purposes, and the dross washed, crushed, and coked.

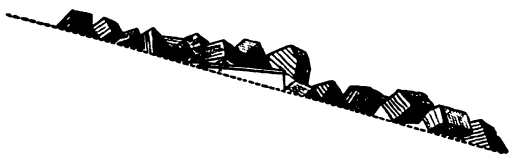
The output is about 500 tons per day, and it is all filled by the colliers with shovels as triping.

The hutches are 3ft. 8ins. long, 2ft. 2ins. deep, and 2ft. 9ins. wide at the top, and 2ft. 2ins. at the bottom. The wheels are 12ins. diameter on the tread, with 17ins. between centres, and a guage of 2ft. 6ins.

There are two common screens used for determining the amount of dirt in the hutches for the purpose of fixing deductions, the scale of deductions in use being:—For 14lbs. dirt, deduct half a hutch; for 28lbs. dirt, deduct a whole hutch. There is a "falling" in the seam worked here. At the other pit belonging to this colliery, where there is no falling, the scale is:—For 7lbs. dirt, deduct half a hutch; for 14lbs. dirt, deduct a whole hutch.

The common screens have each one of Cook's tumblers, and have bars 12ft. long and ½in. apart. The width of each screen is 4ft. 6ins., and the inclination is 1 in 1·60. The bars are 1¾ins. deep, and ⅜in. and ⅛in. thick at top and bottom respectively. These common screens are used for only a very small proportion of the output, the greater portion going over a jigging screen. This jigger, shown on Plate XXIV., is 17ft. long and 8ft. wide, and is supplied with coal by two of Cook's tumblers placed side by side. It has 13ft. of ⅞in. wire meshing, and shoots are arranged so that the lower half may be used for nuts which are not washed. The jigger makes 90 strokes per minute with a 4in. stroke, the motion being derived from a small horizontal engine by means of an eccentric and wypers. The inclination is 1 in 4·80, and there is a 2in. drop in the centre of the mesh to cause the coal to turn over and show any pieces of dirt which might otherwise remain hidden. This drop is made by putting in a

short piece of plate flatter than the screen, as here shown. On the jigger there is a 12in. plate at the top, and a 3ft. plate at



the bottom, from the latter of which four boys pick the dirt just before it falls into the waggon. There is a kepper on this screen similar to those already described, which is worked by a boy, who also attends to the engine and regulates the water supply to the washing machine, according to the quantity of dross being raised by the elevator. The quantity of dirt picked here is so small that it is not worth while estimating the cost of picking.

The whole of the dross is washed by a Coppee washer. The dross falls directly from the screen into a pit, from which it is raised by a bucket elevator. The elevator discharges it into a revolving cone for the purpose of separating it into different sizes before washing. This cone is made of perforated steel plates, and is 11ft. long by 6ft. 8ins. diameter at the large end and 5ft. 4ins. diameter at the small end. The first 7ft. 6ins. has $\frac{3}{8}$in. round holes, and the remainder $\frac{7}{8}$in. holes, and it makes 9 revolutions per minute. This divides the dross into three sizes, which are each carried by a stream of water from the cone to the washing tanks. On the way to the tanks the $\frac{3}{8}$in. size is further divided into two by passing along a rhone with a $\frac{3}{16}$in. perforated bottom, so that the dross arrives at the tanks thoroughly wet, and in four sizes, namely :—Up to $\frac{3}{16}$in. ; above $\frac{3}{16}$in., and up to $\frac{3}{8}$in. ; above $\frac{3}{8}$in., and up to $\frac{7}{8}$in. ; and above $\frac{7}{8}$in.—there being a considerable quantity of the last-mentioned, as the perforations in the wire meshing are $\frac{7}{8}$in. square, and in the cone $\frac{7}{8}$in. diameter. The tanks into which the dross is dropped are ordinary Coppee felspar washers, having gratings and felspar of the size to suit the

various sizes of dross as described in the Cwm-Avon arrangement, illustrated on Plates VIII. and IX. In the tank for the largest size, or

Firsts, the stroke is	5¼ins.,	and speed	50	strokes	per minute.
For seconds,	„	4½ins.,	„	55	„	„
For thirds,	„	3½ins.,	„	60	„	„
For fourths,	„	2¼ins.,	„	65	„	„

The coal is floated over the lip of the tank, and all four sizes are carried into a pit, from which it is elevated to the crusher. The dirt falls through the felspar, and is discharged by a worm from the bottom of the tanks, and is put into waggons by an elevator. The quantity of water used is about 35,000 gals. per hour, and it is pumped up by a pulsometer and used over again, being renewed about once a week. The quantity of dross being washed is about 170 tons per day, but the machine is capable of washing 250 tons per day. There are in attendance on the machine :—

One boy regulating water supply and keeping elevator supplied, at 1s 6d, - - - - - - - -	£0	1	6
One man at tanks, at 2s 8d, - - - - - - - -	0	2	8
One man looking after belts, cone, etc., at 2s 8d, - -	0	2	8
Removing and emptying, say 20 tons dirt, at 2d per ton,	0	3	4
Total wages cost for 170 tons, - - - -	£0	10	2

which is at the rate of 0·70d per ton of dross washed.

The washed coal is crushed in one of Carr's disintegrators, and is discharged into hopper-bottomed bogies, which run on to the top of the coke ovens.

The ovens are of the bee-hive type, filled from the top and emptied from the front, and they contain from 5 to 7 tons per charge, a charge being coked in from 3 to 4 days. There are 133 ovens, yielding about 120 tons of coke per day.

WHITEHAVEN COLLIERY, WHITEHAVEN, CUMBERLAND.

WILLIAM PIT.

THE coal worked here is a good coking coal, the round coal being used for steam navigation purposes, while the worst of the dross is coked or shipped. The colliers fill the whole output with shovels as triping. The hutches are 4ft. long, 3ft. wide, and 2ft. 6ins. deep, and are filled a little above the mouth.

Winding goes on day and night, the quantity raised being about 1000 tons per 24 hours. There are three shifts of hillmen and pickers.

Nine common screens, somewhat similar to those at St. Helens, have been superseded by one jigger screen, over which the whole output is passed. See Plate XXV. The coal is tipped by one of Cook's tumblers on to the jigger, on which it is handpicked, and from which the round coal is discharged into the waggon. The jigger is 20ft. long and 5ft. wide, and is inclined 1 in 4·75. It is hung by four adjustable iron rods, and moves at the rate of 120 strokes per minute, with a stroke of 5ins. It is driven by a pair of eccentrics on a counter shaft connected with a donkey engine, 7ins. by 10ins., by means of a belt 4½ins. broad. The eccentric rods in this jigger are inclined at the same angle as the jigger, not level as in all the other cases reported on. The jigger is provided with 9 feet of ½in. wire meshing and 6 feet of 1in. meshing. but this is altered occasionally for a special contract to 3ft. 6ins. of ½in. meshing, 5ft. 6ins. of ¾in. meshing, and 6ft. of 1in. meshing, The continuity of the screen is broken at the top of the top meshing, and at the top of the lower meshing, by a 2ins. drop, arranged in the same way as at Moresby.

When the common screens were in operation there were 108 pickers employed in the 24 hours, while on the jigger screen there are on the day shift 12 women, 1 man, and 1 boy, and on each of the other shifts 12 boys and 1 man, the boys, of course, requiring to be above 16 years of age.

The cost for picking, assuming the proportion of round coal to be 60 per cent., would thus be :—

12 women at 1s 6d per shift,	£0	18	0
25 boys at 1s 6d per shift,	1	17	6
3 foremen at 3s 4d per shift,	0	10	0
Removing and emptying, say 20 tons dirt at 3½d per ton,	0	5	10
Total wages cost for 600 tons round coal,	£3	11	4

which is at the rate of 1·42d per ton of round coal picked. This cost is increased on account of the work going on night and day, as otherwise pickers could be got at a cheaper rate. The dirt is taken away at the end of the shift and tipped into the sea, which is close by.

There is a washing machine in course of erection for the purpose of washing the dross for coking purposes. It is a modification of the Coppee washer, and it is intended that the waste water will carry the washed and crushed material to the coke ovens.

ELSWICK COLLIERY, NEWCASTLE.

THIS colliery is very old and has two shafts—one, South Elswick, being close to the river, and having a self-acting incline down to it, but no railway connection; and the other, North Elswick, being in the centre of the city, with no surface connection except by carting. The coals worked are very fine coking coals, containing little or no dirt. They are thin, but are worked stoop and room to protect the city, the stoops being left in. The coal is all filled as triping with shovels.

The hutches are very low, being 3ft. 6ins. long, 3ft. broad, and 13ins. deep in the centre. The bottoms are recessed down between the wheels, which are under the hutch. There are no

picking or washing arrangements here, the output being merely separated into coal for house purposes above $\frac{5}{8}$in.; nuts for shipment from $\frac{3}{8}$in. to $\frac{5}{8}$in.; and duff for steam raising below $\frac{3}{8}$in.

The triping is tipped over cart screens having bars $\frac{5}{8}$in. apart, and the dross is allowed to run by means of a shoot to an ingenious automatic elevator, shown in Plate XXVI., worked by the winding engine. This elevator delivers the dross on to a steep screen having a $\frac{3}{8}$in. wire mesh, which separates the duff from the nuts. The latter fall into a waggon, and are therein conveyed to the ship's side.

At North Elswick the coal is all sent away in carts, and the nuts and duff for shipment are filled into hutches, sent down the pit, and hauled underground by an endless rope to South Elswick, where they are raised and put into waggons.

SHIRMOOR COLLIERY, NEAR NEWCASTLE, NORTHUMBERLAND.

THERE are two seams of coal worked at this colliery. The Bensham seam is a steam coal, and is non-coking. It is used for furnaces and locomotives, and is also extensively shipped. It contains a considerable quantity of dirt and is hand picked. The High Main seam is a household coal, and is so clean as to require no picking.

The whole of the output is filled with shovels underground as triping.

The hutches are 4ft. long, 3ft. wide, and 2ft. deep, and hold about 11cwts. The majority have no doors.

The output from the Bensham seam is about 400 tons in ten hours, and the whole of this is tipped by a Cook's tumbler on

a jigger screen 9ft. long and 4½ft. wide, arranged as shown on Plate XXVII. The jigger is inclined 1 in 3·75, and is covered with ⅝in. wire meshing. It makes 120 strokes per minute with a 6in. stroke, and is driven by eccentrics with adjustable centres for altering the length of stroke. There is a sluice regulator at the top of the jigger, worked by a lever to prevent overcrowding. The coal is delivered by the jigger on a travelling table 63ft. long and 4ft. wide, moving at the rate of 70ft. per minute. The coal is picked on this table by 10 men and boys along each side of the table. About 7 tons of dirt and 7 tons of inferior coal are picked out per day, and these are allowed to lie on the platform till the end of the shift, when they are taken away in carts, the dirt to the dirt bing, and the inferior coal to the workmen. Two of the pickers spread the coal evenly over the table so as to expose the stones, as the table is rather overcrowded at times. When the hutches are being examined for fines, pieces of wood are laid on the table so as to distinguish each hutch of coal, and the filler is fined 6d if there is sufficient to fill a box of about 40lbs capacity.

The proportion of dross taken out is about 36 per cent., so that the quantity of round coal picked is 256 tons per day, and the cost is as follows :—

20 pickers at, say 1s 8d per shift, - - - - -	£1	13	4
1 boy at regulator, at 1s 4d per shift, - - - -	0	1	4
1 foreman at 3s 4d, - - - - - - - -	0	3	4
Removing 14 tons, at 3½d per ton, - - - - -	0	4	1
Total wages cost for 256 tons, - - - - -	£2	2	1

which is at the rate of 1·97d per ton of coal picked.

The High Main coal is not picked, but is passed over a common screen, 29ft. long and 5ft. wide, inclined 1 in 1, with ⅜in. wire meshing. The dross from the screen is mixed with the dross from the jigger screen and is not further treated.

ASHINGTON COLLIERY, NEAR MORPETH, NORTHUMBERLAND.

THE coal here is all steam coal, the round being used for steam navigation purposes, the nuts shipped to the Continent, and the duff used for land boilers, &c. The coal is all filled underground with shovels as triping.

The hutches are 3ft. 10ins. long, 2ft. 8ins. wide, and 1ft. 8ins. deep inside, and the wheels are 11ins. diameter on the tread, and 1ft. 6ins. between centres, with a guage of 2ft. They are filled only level with the mouth.

There are four shafts to the colliery, from three of which coal is drawn. These are the Duke Pit, the Carl Pit, and the Bothal Pit. The pits are shallow, and each is fitted with two cages, raising four hutches at a time.

DUKE PIT.

The daily output here is about 900 tons, drawn in 11 hours. This output is put over four common screens and picking tables. The arrangement is shown on Plate XXVIII. Each screen has a tumbler, having a cover which prevents the coal from falling out of the hutch until it is close to the bars so as to avoid a long drop, and can only be applied properly when the hutches have no headings as in this case.

The screens are of the ordinary type, 5ft. wide, with bars 12ft. long and ⅝in. apart, the inclination being 1 in 1·71. There is a kepper at the top end of the bars of each screen, which is worked by one of the boys on the picking table. Each screen delivers the round coal on a travelling table 16ft. long and 4ft. wide, which is usually stopped as soon as a hutch is landed on it, the coal being thinly spread by regulating the kepper at the top of the screen. There are seven boys to each table, and a foreman looks after the whole four tables. The dirt is dropped down through trap doors in the platform into tip waggons, in which it is taken to the dirt bing. The quantity of dirt picked is from 2 per cent. to 2¼ per cent. of the output.

Assuming the coal to be 60 per cent. of the output, or 540 tons per day, the cost for hand-picking the round coal will be as follows:—

28 boys, at 1s 4d per shift,	£1	17	4
1 foreman, at 3s 4d per shift,	0	3	4
Removing and emptying 20¼ tons dirt at 2d,	0	3	4½
Total cost for 540 tons,	£2	4	0½

which is at the rate of 0·97d per ton of round coal picked.

CARL PIT.

The daily output at this pit is about 1200 tons in 11 hours. The whole of this output is tipped over one of Cook's tumblers on a jigging screen 5ft. wide and 12ft. long. See Plate XXIX. In the shoot discharging into the jigger there are 6 feet of bars ⅞in. apart, and the jigger has on it 8 feet of ⅛in. wire meshing. There is a sluice kepper at the foot of the bars for regulating the supply of coal to the jigger. The best inclination for the jigger is said to be 1 in 3·73, but this is steeper than any of those we have examined. The jigger discharges the whole of the round coal on a travelling table 100ft. long and 5ft. wide, moving at the rate of 60ft. per minute. On this table, the coal is hand-picked by 24 men and boys, with a foreman, who walks backwards and forwards on a plank above the table and looks out for any piece of dirt which may be missed, drawing attention to it by striking the table with a stick which he carries for the purpose. At the end of the table the coal, before falling into the waggon, passes over a short series of bars 3ft. long to take out any dross caused by the picking.

When the dross falls through the bars and meshing of the fixed and jigger screens, it lands on a travelling band elevator 5ft. wide, and is carried by it almost up to the level of the pithead plates, where it is discharged into a shoot which carries it back to a jigger screen situated below the coal jigger. On its way to this jigger it passes over a small movable shunt worked by a man, who, when he sees wet dross coming, passes it on and causes it to go to a waggon in which it is taken to the boilers for the use of the colliery. The object of this is to keep the wet dross

off the dross jigger, as it clogs the small meshings. The dross jigger is the same size as the coal one, the meshing used being ¼in. The duff as it falls through is carried away by a leather belt carrier and put into waggons, while the nuts drop from the end of the jigger upon two travelling tables each about 30ft. long by 4ft. wide, where they are picked by 24 boys and a foreman. The jiggers have a stroke of 5ins., and make 110 strokes per minute, and they are driven by eccentrics on a counter shaft connected with a small horizontal engine by belt gearing.

The dirt from all the picking tables is removed at the end of the shift to the dirt bing in tip waggons.

Assuming the quantity of dirt from both coal and nuts to be 2¼ per cent., as at the Duke Pit, and the round coal to be 60 per cent., the nuts 25 per cent., and the duff 15 per cent. of the total output, then in 1200 tons triping there would be 720 tons round coal, 300 tons nuts, and 180 tons duff, and the probable cost for picking would be:—

FOR ROUND COAL.

24 men and boys at, say 1s 8d per shift, - - -	£2	0	0
1 foreman at 3s 4d per shift, - - - - - -	0	3	4
Removing and emptying 16·20 tons dirt at 3½d per ton,	0	4	8¾
Total cost for 720 tons round coal,- - - -	£2	8	0¾

which is at the rate of 0·80d per ton of round coal picked.

FOR NUTS.

24 boys at 1s 4d per shift, - - - - - - -	£1	12	0
1 foreman at 3s 4d, - - - - - - - - -	0	3	4
1 man shunting wet dross at 2s 8d, - - - - -	0	2	8
Removing and emptying 6·75 tons dirt at 3½d, - -	0	1	11½
Total cost for 300 tons nuts, - - - - - -	£1	19	11½

which is at the rate of 1·59d per ton of nuts picked.

If the whole coal and nuts be taken together the cost would be:—

For 720 tons round coal, - - - - - - - -	£2	8	0¾
„ 300 „ nuts,- - - - - - - - - -	1	19	11½
Total cost 1020 tons picked material, - - - -	£4	8	0¼

which is at the rate of 1·03d per ton of picked products.

CALIFORNIA STATE

BOTHAL PIT.

At this pit the daily output is about 1000 tons in 11 hours. The arrangements are almost similar to those at Carl Pit, but the coal being naturally cleaner the coal table is shorter and there is no picking table for the nuts, but merely a travelling band for carrying them to the waggon.

The whole of the output is tipped over one of Cook's tumblers on to a jigging screen with similar arrangements of bars, meshing, and kepper as at the Carl pit. The jigger discharges the round coal on a travelling table 66ft. long and 4ft. broad, on which it is picked by 14 men and boys with a foreman, and from which it falls directly into the waggon without the intervention of bars. The dross from the jigger is carried in the same way as at the Carl pit by an inclined elevator, and landed on a second jigger having a ¼in. meshing, by means of which the duff is taken out and the nuts discharged on a travelling band 2ft. wide, which carries them forward to the nut waggon.

Making the same assumption here as before the cost of picking the round coal would be—

14 pickers at, say 1s 8d per shift, - - - - -	£1	3	4
1 foreman at 3s 4d per shift, - - - - - -	0	3	4
Removing and emptying, say 10 tons dirt at 3½d, -	0	2	11
Total cost for 600 tons round coal, - - - -	£1	9	7

which is at the rate of 0·59d per ton of round coal picked.

There is a scale of deductions for dirt here similar to that in force at the other collieries visited, and the amount of dirt in a particular hutch is ascertained in the following way:—The pit-headman gives orders to examine a certain hutch, and before it is tipped the kepper is allowed to empty itself, so that only the coal to be examined is on the jigger at one time. As soon as the the coal lands on the table a fines box is placed on the top of it, and the dirt picked out as it passes down the table is put into the box instead of being thrown to one side. By this means the quantity of dirt in any particular hutch is ascertained, and the collier fined accordingly.

The tables at Carl and Bothal pits are rather overcrowded with coal.

Most of the boilers at this colliery are fired by mechanical stokers made by Benis, Bolton.

SCOTLAND.

GLENCLELLAND COLLIERY, WISHAW.

DROSS WASHING MACHINE.

THE Dross Washing Machine at Glenclelland Colliery was erected in the summer of 1883, from drawings supplied by Kerr & Mitchell, to John Bell, engineer, Wishaw. A considerable number of machines of the same type have since been made by Mr Bell, and the machine is now known as "Bell's."

Several alterations have been made on the machine at Glenclelland since it was erected, and the drawing on Plate XXX. shows it practically as at present working.

In its general construction it is very similar to other forms of "Bash" washers. The following is a description of the working:—

The motive power is supplied by a 12in. cylinder horizontal engine, working with a 2ft. stroke, and running 40 revolutions per minute. The dross is elevated from the dross hole, *D*, by the elevator, E^1, which is worked by means of a belt from the crank shaft of the engine, and which has 32 buckets, each bucket holding 25lbs. of dross. The dross is conducted from this by a shoot into the tanks of the washing machine, *TT*, and falls upon the perforated plates, *BB*, where it is agitated by the water alternately rising and falling through the holes in the plates. As the dross is agitated, the impurities having the heaviest specific gravity sink to the bottom and rest on the perforated plates, the good dross rising to the top until there is a thick layer of dirt above the valve, V^2.

When this accumulation has taken place, the valve is opened and the dirt falls to the bottom of the tank, where again the valve, V^1 is opened, and the dirt falls into the chamber containing the dirt elevator, E^2. This elevator has 30 buckets, each holding about 8lbs.; and by it the refuse is lifted and discharged into a hutch to be conveyed to the dirt bing.

The valve, V^2, stretches the whole way across the plate, *B*, and is in the section of the shape shown by Plate XXX.

The valves, V^1 V^1, are simply half hollow balls fitting into circular holes, and are lifted and lowered by means of levers at the sides of the tanks within reach of the man attending the machine.

The good dross is pushed over from the front of the tanks by the skimmers, *SS*, and passes down the shoot into the revolving riddle, *R*. This riddle is 11ft. 6in. long, and is divided into meshes to suit the separation of the dross into peas and nuts. The first division—2ft. in length—where the water strikes the riddle, is of fine mesh, $\frac{3}{16}$in. The water is removed by this, and carrying with it the smallest of the dross, it passes along a rhone to the front of the boilers where there is a small revolving riddle of *very fine* mesh, which removes the dross and passes it to the front of the boilers ready for firing.

The special feature of this machine, and that by which it differs from previous washers, is that the agitation is produced by means of a piston working in a horizontal cylinder, *AA*. The working part of the cylinder is bored out, and is 33in. diameter. The motion to the piston is communicated by a parallel eccentric motion, worked from the shaft, S^1. It is geared to work at 80 strokes per minute. The length of the stroke is 4½in. The water is introduced at the ports, *WW*, one for each tank, between the agitating cylinder and the tanks. The water comes from a water tank, the bottom of which is about 12ft. above the level of the top of the dross tanks, and is pumped up to it by means of a 9in. ram, with a 12in. stroke, worked off the crank of the engine.

As the piston moves backwards and forwards in the agitating cylinder, the water in each tank alternately rises and falls, the water in the one tank rising while it falls in the other. Strong agitation is thus produced, the amount depending on the size of the cylinder and the length of the stroke.

The horizontal cylinder was adopted for the sake of both economy and efficiency. The construction is less costly as there is only one cylinder to bore, and gearing required to produce motion for one piston instead of for two. The power required to

drive for the same agitation should also be less, as there is less friction and complete reciprocity of motion.

The results of the working of the machine have been very satisfactory, and although it was erected more than six years ago, when there was very little attention paid to washing, it probably still works as well as any of the ordinary Bash machines, the great point in its favour being strong agitation, which, it is hardly necessary to say, is required for clean washing.

There was some difficulty found at first in keeping the piston tight owing to its weight. To help this, a bracket, *K*, as shown in the plate, was fixed to bear up the outer end of the piston rod, and a system of gutta percha rings round the piston has been adopted.

These rings are made out of old pump bucket gutta percha, and measure 2in. × 1in. section. They are put in place of the ordinary metallic piston rings, and, according to the condition of the cylinder, they last from one to six months, and require to be renewed to keep the piston tight.

Experience has shown that the chief defect of this washer, as of all the ordinary Bash machines, is that in spite of constant renewal of the perforated plates, *BB*, the holes through which the water passes wear so quickly that it is impossible to prevent some of the very fine dross from passing down through the plates and being carried away with the dirt.

The only way to get completely over this difficulty is to size the dross before washing, and to wash the small sizes in a more suitable machine, such as the Robinson's, or, perhaps, better, a Bash washer with the use of felspar on the top of the plates. The defect is increased by the *sucking* down of the water through the holes in the course of agitation. This might be partially overcome by giving a slow downward motion and a quick upward motion to the water, which might be arranged by means of some form of link motion, although not in conjunction with a horizontal cylinder.

A further defect is the valve arrangement for dropping the dirt from the perforated plate. Its efficiency depends too much on the care of the attendant, and it would be a great improvement to have some form of automatic dirt separator. A very

simple form of such a separator is that of a wheel with little buckets working at the side of the tanks in communication with an outlet for the dirt. This form is used in Continental machines, and works well, there being an arrangement by which the communication can be adjusted to prevent any dross passing through. The machine will wash rather more than 100 tons daily.

Reference Index to Plate XXX.

C. 12in. engine supplying the motive power.
D. Dross hole, from which dross is lifted.
E^1. Dross elevator.
F. Fly-wheel on agitating shaft.
S^1. Agitating shaft.
A. Agitating cylinder.
WW. Ports for water to enter tanks.
TT. Tanks for washing.
BB. Perforated bottoms in tanks.
V^2V^2. Valves to let dirt fall from perforated plate.
V^1V^1. Half-ball valves to let dirt down to dirt elevator.
SS. Skimmers to push washed dross towards riddle.
R. Revolving riddle for screening dross.
E^2. Dirt elevator.
P. Position of 9in. ram, working from crank of engine.
K. Bracket for bearing up end of piston rod.

BLAIRHALL COLLIERY, PERTHSHIRE.

THE following is a description of Plate XXXI., which is a plan of the Coal-screening, Picking, and Washing arrangements at the Coltness Iron Company's Blairhall Colliery, No. 3 Pit, Perthshire; by Mr Robert Russell, General Manager of the Company:—

A. Pit.

B. Pithead scaffold, 24ft. above rail level.

C. Hutch tipper.

D. Oscillating screen and picking table combined, driven by an 8in. cylinder engine; angle 3ins. per foot; speed about 120 strokes per minute—3in. stroke. Capable of passing 40 tons per hour.

E. An iron trough laid at an angle of one inch and three-quarters per foot, conveying the unwashed dross from the screen to the washing tanks by means of the water circulated by the centrifugal pump *r*.

F. Two cast iron washing tanks, each capable of treating 7 tons of dross per hour, in which, by an agitation caused by means of leather valves attached to the tank, and an eccentric rod, the coal and dirt are separated. The dirt being heaviest falls to the bottom, and is from time to time let off by a valve into a tank, *a*, whence it is elevated by buckets attached to an endless chain, *b*, to the point, *c*, where it is emptied on the shoot *d*, down which the dirt runs to a hutch, *e*, standing upon the pithead scaffold which, when filled, is emptied upon the dirt hill. The dross being lightest, is floated over a notch near the top of the washing tanks into a trough, *f*, thence into

G. A Trommel, which is laid at an angle of 1½ins. per foot, in which the washed dross is sized suitable for the market; in this case into

1 Duff, or Fine Coal, which, along with the water, is conveyed in a trough, *g*, laid at an angle of a quarter of an inch per foot, to a revolving scooped drum, *h*, of perforated zinc, from which the duff is deposited into a tank, *i*, the water passing on by the trough, *j*, to another revolving drum, *k*, of brass wire, having 2500 meshes per square inch, the fine coal

caught by it being also deposited in the tank, *i*, and together elevated by buckets, *l*, to the point *m*, from which it runs down a shoot to a hutch, *n*, standing upon the pithead scaffold, which, when filled, is conveyed by the endless ropeway to be used in firing the steam boilers of the colliery, which are all at No. 2 Pit. The water, after leaving the revolving drum, *k*, runs in a wooden trough, *o*, to a series of four small settling ponds, *p*, where it is sufficiently rid of sludge to enable it to be used over again. Out of these settling ponds it overflows into a regulating tank, *q*, in which the water rises and falls according to the way in which the centrifugal pump is performing its work, and in the event of stoppage of machinery it acts as a reservoir, and so prevents not only dirty water from finding its way into streams from the overflowing of the settling ponds, but also conserves water which would otherwise be lost. The circuit of the water is completed by a pipe connection from the regulating tank to the centrifugal pump, *r*, which forces the water by way of the piping, *s*, to the iron trough *e*, which receives the unwashed dross under the screen.

2 Peas, an excellent fuel for steam-raising, which falls into a waggon underneath.

3 Nuts, which also fall into a waggon underneath, but these are rinsed before reaching the waggon, as they are principally used for household purposes. The water used in the rinsing is conveyed to the regulating tank by a small wooden trough, *w*.

4 Jumbo Nuts also fall into a waggon underneath. They may either be loaded and disposed of separately, or, as in this case, along with the round coal.

H. A small cistern for supplementing the water supply, and fed by the boiler pump, situated at No. 2 Pit. It has a connection, *t*, to the trough under the screen, and *u*, for the rinsing of the nuts.

J. A small settling pond for clarifying the little waste water which finds its way there by way of gutters and drains, *v*, from the drippings of the peas and nuts, waggons, &c.

EARNOCK COLLIERY, HAMILTON.

THE following description, illustrated by Plate XXXII., of the arrangement for Screening and Cleaning Coal at Earnock Colliery, is by Mr James Gilchrist, Manager :—

The new arrangements for screening and cleaning coal which have only recently been erected, consist of four jigging screens, which separate the dross from the round coal. The round coal then passes on to travelling bands or tables, where it is cleaned. At the end of three of these tables there are short fixed screens, where any dross is taken out that has been made in breaking the coal to clean it, before it enters the waggon.

Previous to the erection of the above machinery, the coal was passed over seven fixed coal screens and one triping shoot. All the screens were double and had a movable plate in the centre, on which the coal was picked; but the system, although a good one, was slow, and therefore abandoned in favour of the more expeditious one of cleaning and separating on the travelling tables.

Plate XXXII. shows the arrangements in plan and elevation. A brief description of the scaffolding, which is mostly iron, may be interesting. As shown on the Plate, there are two levels, the lower one being 11ft. 6in., and the upper one 24ft. above the level of the rails.

The uprights on which the scaffolding is built are cast-iron columns, 21ft. 9in., by 12in. dia. at the bottom, tapering to 10½in. at the top. The columns are connected at the top by rolled iron I beams, 12in. deep by 6in. broad. These beams are crossed by lighter iron beams 7⅛in. by 3⅛in., on which are laid malleable iron plates, 6ft. by 3ft. by ⅛in.

The beams connecting the columns at the lower level are 12in. deep by 5in. broad, for the wide spans, and 10in. by 5in. for the shorter spans; these beams are covered with wood. On the top of the principal iron beams are placed cast-iron columns, 8ft. by 5in. dia., which support the roof, the roof and sides being covered with corrugated galvanised iron sheets. The scaffolding is well lighted from the roof.

Three tables, Nos. 1, 2, and 3, are used for cleaning coal, and No. 4 for triping.

In the Plate the elevation of No. 3 table is omitted to avoid unnecessary complication, but it is of similar construction to the others. On looking at the elevation of Nos. 2 and 3 tables it will be observed that the coal is tipped from the hutch by an ordinary Scotch tipper on a fixed plate about 4ft. long, and projecting 6in. over the top end of the jigging screen. This plate is lying at an angle of 26 degrees. Passing over the fixed dumb plate the coal is received by the jigger, which is composed of two steel plates 15ft. long by 2ft. broad and $\frac{1}{2}$in. thick, placed parallel and 4ft. apart. At the top of the jigger there is first a dumb plate of 12in. broad, then—in No. 1 jigger—screen bars, 12ft. long, composed of steel bars $1\frac{3}{4}$in. deep by $\frac{3}{8}$in. at top and $\frac{3}{16}$in. at bottom, and $1\frac{3}{8}$in. apart. There is then another dumb plate 2ft. broad; this plate projects 6in. over the travelling table.

It will be seen that the jigger for No. 3 picking table has perforated plates instead of scree bars. They are arranged as follows:—At the top of the jigger is a dumb plate 12in. broad, then a $\frac{1}{2}$in. steel plate 1ft. 9in. broad. This plate is full of holes $1\frac{1}{4}$in. dia., the pitch being $1\frac{3}{4}$in.; the other five plates are cast-iron, 2ft. broad and $\frac{1}{2}$in. thick. The holes in these plates are $2\frac{1}{4}$ in. dia., the metal between the holes being $\frac{3}{4}$in.

Since the plan was prepared, the scree bars have been taken out of No. 2 jigger and perforated plates put in.

The small coal in passing down the jigger screens does not jam so readily in the holes in the plates as it did in the screen bars.

The screens are hung by four iron rods $1\frac{5}{8}$in. in dia. from the beams above, and are inclined at an angle of 13°, the dumb plates at the lower ends having an inclination of 26°, and projecting 6 inches over the picking table. The picking tables are about 34ft. long by 4ft. broad, and are composed of iron plates 4ft. long by $8\frac{3}{4}$in. by $\frac{1}{4}$in., fastened by snugs, which are rivetted into the plates, to a long linked chain which is passed round hexagonal drums at each end. The plates overlap each other $1\frac{3}{4}$ inches. The gearing wheels for driving the tables are fixed on the ends next the jiggers.

The jiggers pass the round coal, free from dross, to the picking tables, where all the stones, brasses, &c., are picked out by boys stationed on each side of the band, and then the clean coal is passed over a fixed screen so that any dross that has been made on the band may be taken out before the coal is loaded into waggons. The bars of the screen are 6ft. long, and inclined at 32°. To facilitate loading and avoid breakage, there is a swinging platform, under the control of the trimmer, at the foot of the screen, and from this the coal is dropped into the waggons.

Nos. 1 and 2 picking tables and their jiggers are driven by a horizontal engine, 8in. dia. by 16in. stroke, and running 120 strokes per minute. The engine is fixed on the upper scaffold, and is connected by a diagonal shaft with the main shafting on the lower level; this shaft is 2⅞in. dia., and makes 60 revolutions per minute. The gearing wheels for driving the tables are 7 to 1, so that the tables travel at the rate of 40ft. per minute. The shaft on which the eccentrics are for driving the jiggers, is 3½in. dia., and makes 110 revolutions per minute; the throw of the eccentrics is 4 inches. No. 3 table and jigger are driven by an engine similar in every respect, and connected in the same manner as already described, provision in this case being made for another table and jigger if required.

At each coal table there are three boys and one man, whose duty it is to pick out all stones or other impurities.

The arrangements for the triping picking table and jigger are slightly different, as shown on the Plate. The jigger is hung so that it carries the coal backwards, instead of forwards, to the travelling table, which is built above the line of rails on which the waggons are, and into which the coal is loaded.

This jigger is also so arranged that the dross can be taken from the coal if no triping is required.

The gradient of the jigger is 13°, or 1 in 4·5.

The engine cylinder for this jigger and table is only 6in. dia. by 12in., and runs 80 strokes per minute. The shaft for driving the jigger is 4 inches, and swelled in the centre to 4¾ inches, and is coupled up direct with the crank shaft.

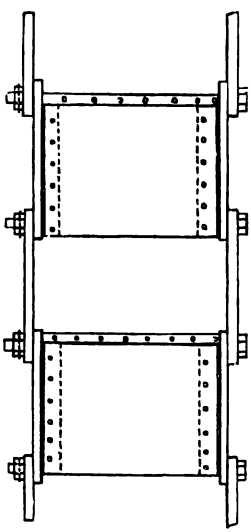
The stones, brasses, and bad pieces of coal picked from the tables are filled into hutches, brought alongside for the purpose,

and in them the dirt is taken to the tip. The brasses, if any coal is adhering to them, and inferior pieces of coal, are taken to a crusher, where they are broken up into small, not exceeding one inch cube. The small passes into the dross hopper, where it is raised by the elevator in connection with the washing machine.

The dross from Nos. 1 and 2 jiggers passes down the dross shoot into the waggons, and the dross from No. 3 jigger falls on a dross conveyor, and is carried to the dross pit or hopper. Dipping into this pit is the main elevator by which the dross is lifted for the nut jigger screen and washer.

The main elevator is 50 feet long.

The pitch chains are made of best mild steel, each link 14½ins. long, by 2¼ins. by ¾in., having two holes bored in each at 12in. centres. There are no double links in this chain. The buckets are 14½ins. by 11½ins. by 10½ins. The sheet that forms the front and back is ⅛in. thick, and the ends $\frac{3}{16}$in. thick. The ends project at the back of the bucket 2 inches, having two ⅞in. dril-

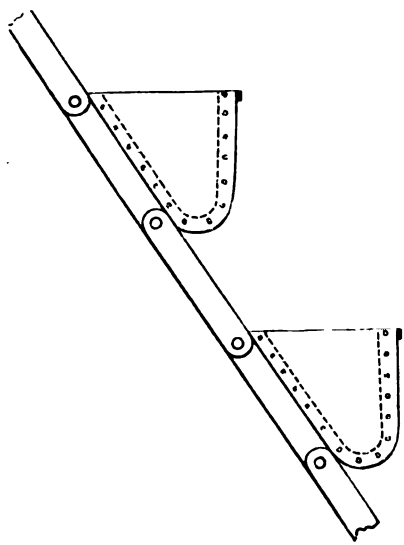


led holes on each side at 12in. centres for attaching to pitch chains. The buckets and links are fixed together with mild steel bolts, ⅞in. dia., the bolts being turned where they pass

through the end plate of the bucket and the links of the chains. To prevent the nut of the bolt from working off, a hole is drilled through it and the bolt, and a split pin put through both.

No rollers are used. The pitch chain and buckets are guided by an angle iron on each side.

The accompanying figures show buckets and chains connected.



The dross is conveyed by a short shoot to the nut jigger. This jigger is 16ft. long by 2½ft. broad, and the inclination is 1 in 2·6, or 21°. It is driven at the rate of 100 strokes per min. The plates for separating the nuts from the dross that goes into the washer are 12ft. long, and are perforated with 1¼in. holes, having a 2in. pitch. The nuts are passed to a travelling table, 29ft. long, where all stones and brasses are picked out by boys, and the clean nuts are conveyed from the end of the table into a hopper capable of holding a waggon load, and which is emptied when convenient.

The dross that passes through the 1¼in. perforated plates falls through a shoot into a

ROBINSON'S WASHING MACHINE.

This machine, which is illustrated on Plate XXXIII., consists of a truncated cone, inverted, measuring 8ft. dia. at top, 1ft. 10ins. dia. at bottom, and 6ft. 6ins. deep. The plates are steel, ⅜in. thick. A strong shaft is fixed vertically, to run in the centre of the cone; on this shaft is a cast iron crosshead, to which are bolted 4 cross arms of oak, 8ins. by 6ins. To each of these cross arms are bolted 3 heavy malleable iron bars, projecting down so as almost to touch the sides of the cone or washer, and on the bottom of the driving shaft are bolted 4 shorter arms, all as shown on Plate XXXIII.

At the same time as the dross is falling into the cone, a stream of water is being forced in at the bottom, through the cast iron bottom piece, which is covered on the inside by the side plates, having 8 rows of ½in. holes. The shaft, with crosshead and depending arms, revolve inside at the rate of 14 revolutions per minnte.

The dross coal is carried by the water over the side of the washer, and the heavier particles—brasses and stones—fall to the bottom. Fixed on the side of the washer, with a suitable inclination, is a sheet of finely perforated zinc, 6ft. by 3ft. by 0·55in., with 72 holes per sq. inch.

In passing over this zinc sheet the water is separated from the dross, which is again elevated and carried along a shoot into a hopper placed conveniently for loading the washed dross into waggons. Before this dross passes into the hopper, an arrangement is made in the shoot, by perforated plates, for drawing off part of the finest dross for the boiler fires.

The brasses and stones which gravitate to the bottom of the washer are removed by means of the valve arrangement shown in the illustration, the upper valve being always closed before the lower one is opened. The debris is also elevated into a hopper, where it is drawn into a hutch and run out to the dirt heap.

The water separated from the dross by the perforated zinc sheet carries with it several tons per day of very fine particles of coal, but this is caught in the following manner:—The water is run back in wooden rhones to the tank in connection with a pulso-

meter pump. The rhones are 6 feet higher than the tank. The last rhone is deeper than the others, and is 18 inches wide, with a fall of 5¾ins. per yard. When the water enters this rhone, it runs on a sheet of zinc, having 232 holes per sq. inch. The water passes through the holes, leaving the very fine dross to fall over the end of the rhones. It is then filled into waggons and carried to the boilers and used there for firing.

A No. 9 pulsometer is used for pumping the water, which is forced direct into the washer, in preference to pumping the water into a tank 30 feet above the washer, and regulating the flow into the washer by a valve. A certain quantity of fresh water is added daily to that in use, but no record of the quantity is kept; but the oftener the water is changed the better it is for the fuel washed. There are two settling ponds in connection with the washer, but they are now very seldom cleaned out. On the side of the last pond there is placed a No. 4 pulsometer pump, which pumps all the dirty water that is allowed to run away from the washer on to the top of the dirt heap. A considerable quantity of fine sludge is thrown on the top of the heap with the water, but the heap is a perfect filter, the water leaving the bottom of it being as clear as it was before it first entered the washer.

The washer was erected to wash 20 tons per hour.

The engine for driving the washer, three elevators, nut jigger, nut picking table, dross conveyor (60ft. by 3ft.), and the coal crusher, has a 14in. cylinder and 2 ft. stroke, running 56 strokes per min.; pressure of steam in boilers, 50lbs. All the different parts of the machinery described are driven by shafting connected by bevelled gearing, except the crusher, where belting is used as a much simpler mode of getting up the speed necessary.

CRAIGHEAD COLLIERY, BLANTYRE.

THE following is a description of the washing plant at Messrs Wm. Baird & Co.'s Craighead Colliery, near Blantyre, illustrated by plan and elevations, Plates XXXIV. and XXXV. The machinery was all made and erected by Messrs Lamberton & Co., engineers, Coatbridge :—

The coal is drawn up two pits 36ft. apart. The coal from No. 1 Pit is tipped on the shaking screen *A*, driven by the engine *B* erected on a brick and cement seat. The connecting rod ends are all fitted with adjustable brasses.

The arrangements at the bottom of the screen (not shown on the drawings) are such that the coal may be delivered into waggons on either No. 2 or No. 3 siding. The dross is conveyed by the shoot *C* into the hopper *D*, from which it is elevated and delivered into a Robinson washer cone *E*.

The coal from No. 2 Pit is tipped over an ordinary screen *F* into a travelling table, which delivers the clean, round coal into waggons on siding No. 4, and the dross is carried by a shoot to the hopper *G*, whence it is elevated and delivered into the washer cone *H*.

Both cones *E* and *H* are 7ft. 6ins. diameter at the top, and are built of cast-iron segments. Water is pumped from the tank *I*, by two No. 8 pulsometers *J* directly into the bottom of each cone. The machinery is driven by two 10ins. vertical trunk engines *K*, working independently of each other, and regulated by Pickering's governors to run at a speed of 120 revolutions per minute. The iron agitating arms in the cones revolve ten times per minute.

The dross and water from both cones are delivered into the revolving riddle *L* by the trough *M*, in the bottom of which is a fine wire mesh, allowing about one half of the water to pass directly back into the tank *I* by the pipe *N*. The riddle *L* 3ft. in diameter, lies at a slope of 1 in $3\frac{3}{4}$, makes 16 revolutions per minute, and is driven by intermediate gearing, which may be connected to either engine.

It is arranged to separate the dross into five sizes, viz., duff, peas, small nuts, large nuts, and jumbo nuts. The remaining

water passes out along with the duff, which it carries along the shoot *O* to the strainers *P*, fitted with perforated zinc plates, through which the water passes and runs back to the tank *I*, and the duff falls into waggons, or goes direct into the boiler stoke hole. The peas, small nuts, and large nuts are carried by shoots S_1, S_2, S_3, into the tanks R_1, R_2, R_3, respectively. The tanks are parts of old boilers set on end, fitted with two valves in the bottom. They hold from 7 to 8 tons each, and the waggons are filled from them as required.

The jumbo uuts pass out from the end of the riddle, and run down shoot S_4 direct to a waggon. The nuts, as they pass down shoots S_2, S_3, S_4, are rinsed by powerful squirts supplied with water by a small Worthington pump.

The dirt in the dross is separated from the coal by the upward stream of water in the cones of the washers, and falls gradually to the bottom, whence it is drawn by means of the two valves in the casting *T*. The levers working these valves are carried up to the engine platform, so that the whole machinery is under the immediate control of one man. *V*, *V* are pipes fitted with sluice valves, and connected to the casting *T* above the upper valve, so that any dirt that lodges in the pipes and annular space round the bottom of the cone may be readily removed.

The whole of this arrangement, which is capable of washing 400 tons of dross per day of 10 hours, works very regularly without breaking down and stopping the pits; and the nuts, &c., are delivered into the waggons bright and free from dirt.

LODGE COLLIERY, SLAMANNAN.

MR THOMAS THOMSON, the manager of this colliery, furnishes the following description, illustrated by Plate XXXVI., of a trough washer at work there. The trough system has been in use in Slamannan district for many years for the cleaning of dross preparatory to coking.

Referring to Plate XXXVI., it will be seen that the machine consists of a double trough, about 100ft. long, 4ft. wide for a part of its length, and 3ft. for the remainder. The bottom is of steel, $\frac{1}{4}$in. thick, and the sides and centre division are of iron, $\frac{3}{16}$in. thick. The trough has a fall of 1 in 22. Underneath it, along the greater part of its length, is another channel of concave shape, lying at a somewhat steeper inclination, with openings into the upper trough covered by stoppers *D*.

The dross is tipped into one or other of the two divisions of the trough at *A*—a tongue being placed, as shown in fig. 3, which can be flung over from the one side to the other alternately, so as to divert the dross into the one division while the dirt is being removed from the other. Water is admitted by the pipe *B*. At each of the points *C* there is an intercepting strip or sliding sluice put into the trough immediately above the dirt openings *D*. Fig. 4 shows a side view of the trough, with two of the strips intercepting a quantity of dirt, and the clean dross passing over. When the trough is filled with dirt to the level of these strips, the water and dross are turned into the other division of the washer, which has meantime been cleaned, and the stoppers *D* are taken out, the strips *C* lifted, and the dirt allowed to pass into the lower trough, in which it is carried by the current of water to *E*, where it is loaded into hutches and conveyed to the dirt heap. Each stopper is simply a close-fitting, movable portion of the bottom of the trough, its whole width and about 6in. long, with a handle *f* of $\frac{3}{4}$in. iron by which to lift it out as required. When the stopper is in its place, the bottom of the trough is continuous, with no interruption except the handle sticking up in the centre

The washed dross leaves the washer at *G*, and is then ground before being put in the coke ovens.

Two girls and one man are in attendance, the girls being employed in agitating the dross in the upper portion of the trough and in cleaning out each as required.

The water used is supplied by two 10in. plungers of 3½ft. stroke, going at the rate of seven strokes per minute, and is pumped into a tank, from which it is drawn as needed.

The machine washes about 100 tons per day of ten hours, with a loss of about 20 per cent. of dirt, at a cost, for wages, of 2¼d per ton of washed dross.

LONGRIGG COLLIERY, SLAMANNAN.

SELF-CLEANING TROUGH WASHING MACHINE.

THE following description, illustrated by Plates XXXVII. and XXXVIII., is by Mr James M'Killop, of the firm of James Nimmo & Coy. :—

The institution of coal washing for the purpose of separating small coal from its accompanying impurities has been associated with the Slamannan coalfield for more than 20 years, and from the specific gravity and varied elements connected with the coals, there is probably no mining district in Great Britain which tests the various methods of coal washing more thoroughly than the Slamannan district. Indeed, a washer adapted in every way to wash the different qualities of coal in this district, and present them to the consumer free from all impurities, could hardly fail to meet the requirements of any locality with acceptance.

The washing in the earlier period of the process was on the trough principle, which was found suitable as far as the market was concerned. The objections to it, however, were a limited output, and high cost in consequence. In order to obviate these as

much as possible, operators were induced to speculate on other modes of washing, and large sums were spent in testing their varied principles, the result of all such being that up to this date no principle has been found so adaptable to the requirements of the district as the old one.

The coal dross of the district has a heavy specific gravity (the carbon reaching even as high as 90 per cent.), and in the state in which it is often put into the washing machine is accompanied with impurities varying from 20 to 50 per cent. The close relation which these two elements bear to each other, not only in weight, but in the pastiness in which they are allied, makes separation very difficult, and in practice it is found that the churning or agitating process makes the dross quite unsuitable to meet the favour of customers, and particularly that of the most fastidious of all customers—the blacksmith.

The method adopted at Longrigg Colliery for the washing of dross is the trough principle, but extended from the old form of stationary dams and sluices to a set of travelling scrapers about 4 feet apart and 2 inches deep, fixed on an endless chain, which, by moving along the bottom of the trough against the stream of water and dross, delivers, in a self-acting form, the dirt at the upper end of the run, and the marketable dross at the lower end. This will be easily understood from Plates XXXVII. and XXXVIII.

The trough in use is 60ft. long, 2ft. wide, and 11ins. deep, set to a gradient of 1 in 18. The dross and a portion of water are introduced at 15ft. from the upper end of the run, the balance of water through a regulating valve being supplied at the extreme upper end.

This self-cleaning trough washing machine is meantime washing a daily supply of 200 tons of dross, and was erected by Messrs Inglis & Hossack, engineers, Airdrie.

HALLSIDE COLLIERY, NEWTON.

THE arrangement of screens at this Colliery has been designed by Mr James S. Dixon, M.E., who furnishes the following description and drawings shown on Plate XXXIX. :—

As will be seen on the drawings, the arrangement as at present designed consists of three screens, two with moving picking tables, and an ordinary screen for hard coal. These screens are erected parallel with the lines of rails, and the hutches all run from the pit into rocking cradles and are tipped sideways, no doors being required. The hutches are 4ft. 2ins. long, 2ft. 9 ins. wide, and 18ins. deep, and hold about ten cwt. of coal. At present screens No. 2 and 3 are erected, No. 1 will be as soon as the output increases. By the arrangement shown, the shed being lighted from the roof, the light inside is as good as that outside, so that picking can be done under the best circumstances.

The outstanding feature of the arrangement is the introduction of a slow moving conveyor *B*, which arrangement was previously in operation at Newton Colliery, for the purpose of slowly distributing the coal over the screen *D* and on to the picking conveyor *A*. The hutch is emptied into the hopper *C*, from which the coal is taken uniformly away by the conveyor *B*, moving at a rate of about 15 to 20 feet per minute. It then slowly falls over the screen *D*, with bars 5ft. long, where it is thoroughly freed of dross, on to the picking conveyor *A*, moving at about 30 to 40 feet per minute, where the rubbish is removed. It then passes over the screen *E*, with bars 5ft. long, which removes any further dross, and slides down the shoot *F*, which is at an inclination of 1 in 2½, into the waggon. The dross from the screens *D* is taken by the conveyor *G* outside the shed to a waggon, or to the washer elevator pit, should such be erected. The dross from *E*, being somewhat rounder, is picked on the conveyor *H* and re-screened, the small being carried into the dross waggon, the round making nuts. The rubbish is removed by the conveyor *I* outside the shed.

BENT COLLIERY, HAMILTON.

THE following is a description by Mr Jas. S. Dixon, M.E., General Manager to the Bent Colliery Company :—The nut making at this colliery is conducted on the dry principle by riddling and picking. A drawing of the arrangement is shown on Plate XL. The dross is carried from the screens by the conveyor *A*, from the end of which it falls down the shoot *B* to the dross pit *C*, whence it is lifted by the elevator *D* to the top end of the circular riddle *E*. This riddle is hung at an angle of 1 in 4, and revolves at about twenty revolutions per minute, and is divided into three sizes of mesh, as follows — 10ft. of $\frac{3}{16}$in., 8ft. of $\frac{3}{4}$in., and 6ft. of $1\frac{1}{8}$in. Any larger than this, being the irregular shaped pieces which pass through an ordinary screen, but not through the square meshes of the riddle, pass out at the end to the conveyor *F*, where the stones are removed and the nuts are delivered by the shoot *G* into the waggon below.

The nuts from $\frac{3}{4}$in. to $1\frac{1}{8}$in. are delivered on the conveyor *H*, where the stones are removed, and the coal is delivered by the shoot *I* to the waggon below.

The peas $\frac{3}{16}$in. to $\frac{3}{4}$in. are delivered direct by the shoot *J* to the waggon below.

The dust which passes through the $\frac{3}{16}$in. mesh falls into the trough of the spiral conveyor *K*, which takes it a distance of about 150ft. to the boilers. Any surplus dust is delivered by the shoot *L* into a waggon on the same line of rails as the largest size of nuts—there being only a limited quantity of each.

The whole is driven by the upright engine *M*, which has a cylinder of 10in. diameter and 2ft. stroke, and is geared 3 to 1, and goes about 75 revolutions per minute.

The picking conveyors *H* and *F* move at about 25ft. per minute, the pulleys being driven by $\frac{3}{8}$in. short-linked chain.

The stones and refuse removed amount to 2 to 3 per cent.

The quantity of dross passed through this machine is about 1000 tons per fortnight, and the wages for that period amount to about £9. The cost per ton for wages is therefore 2·16 pence.

DALDOWIE COLLIERY, BROOMHOUSE.

THE following is a description of the screening arrangements at the Daldowie Pit of Messrs Dunn Brothers, near Broomhouse, furnished by Mr Robert Gibb, manager :—

The seams of coal worked are the Pyotshaw, Main, Splint, and Virgin Seams. The coal as dug by the miner is filled into hutches 3ft. 11in. by 2ft. 4in., by 1ft. 6in., having an average load of 8½ cwt. The hutches have end doors, and rocking tippers are used.

The fitting comprises two common screens and a jigger screen. One of the common screens has bars 14ft. long, and 1¾ins. apart, and the other has 17ft. bars 1½ins. apart. The jigger screen and connections are shown on Plate XLI.

The jigger screen *A*, which is composed of wire meshing, is 12ft. long and 4½ft. wide; lies at a gradient of 1 in 5½, and is suspended by ash springs.

It is moved by means of eccentrics with a stroke of 4ins., at a speed of 100 strokes per minute for coal having 25 per cent. of dross, the speed being increased with an increase of dross, so as to pass one ton of coal per minute.

This screen delivers the coal on a travelling band, *B*, 27½ft. long and 4ft. wide, made of iron plates, where it is picked by three men. It then passes over a screen, *C*, of round bars 3½ft. long and 1½in. apart, and falls into a shoot, *D*, lying at right angles to the screen, and having a balance plate, *E*, which delivers the coal gently into the waggon.

The rubbish picked out of the coal, amounting to about 1½ per cent. is loaded into waggons and removed.

The dross from the jigger screen is delivered on a travelling band, *F*, 30 feet long and 2½ feet wide.

That which passes through the short screen *C*, from the picking band *B*, is conveyed by means of a band, *G*, to the band *F*, which receives also the dross from the common screens above referred to, and delivers the whole dross into waggons at *H*.

TRABBOCH COLLIERY, NEAR AYR.

THE following is Messrs John Galloway & Coy.'s description of the coal screening and cleaning arrangements at Trabboch Colliery, Ayrshire, illustrated by Plate XLII. :—

The coal, immediately after being weighed on one of Henry Pooley & Sons' patent self-indicating hutch weighing machines, fitted with a turning table so as to make the hutches easily diverted, is run upon a tipper of a very simple construction and emptied down a shoot to a small travelling belt or conveyor, 7ft. long by 4ft. wide, which conveys the coal and distributes it evenly on the jigging screen.

This screen is placed at an angle of 10°, equal to 6·207 inches per yard, and is 13ft. 6in. long, by 4ft. 6in. broad over all, and separates the coal into three different sizes. The frame is made of $\frac{3}{16}$in. mild steel plate and steel angle, rivetted together and bound round the edge with cape iron. The bottom is close, and made of $\frac{1}{8}$in. steel plate, and has a shoot on each side, one for delivering the nuts into waggons, and the other for delivering the small into a hutch or other conveyance that may be found most suitable. The small in this case is delivered into a hutch and conveyed a short distance to a steam hoist, where it is elevated and emptied into the dross holder for fuel for the boilers.

The screening surface for the large coal is 10ft. by 4ft., and is formed of strong steel wire, $\frac{1}{4}$in. in diameter, woven around the cross rods lengthways, and is perfectly smooth. The cross rods are six inches apart, and the distance between the wires is one inch, formed by turning the wire four times round the cross rods.

The screening surface for the nuts is 9ft. by 4ft., and consists of a steel plate, perforated at $\frac{3}{8}$in., and placed at an angle of 14°, equal to 8·75 inches per yard.

The shoots on each side of the screen are placed at an angle of 11°, equal to 7·96 inches per yard.

The screen is suspended from the sides by four short rods, made of tough ash, and fixed by a simple construction in cast iron brackets, the upper ones working in cast iron bushes set on the frame for carrying the screen.

The motion of this screen is transmitted from a small coupled engine, which likewise drives the conveyor and picking table by intermediate chain pulleys and geared, the chain used being the ordinary short link construction, and $\frac{3}{8}$in. diameter.

The reciprocating motion of the screen is caused by a pair of eccentric sheaves, working on a shaft with two fly wheels, at the front of the screen and connected by rods in the jigging portion of it; the throw of the eccentrics is four inches.

The framing for carrying the jigging screen and appurtenances is 8in. square pitch pine.

From the screen the coal falls on a Greenfield coal picking table, made by Kesson & Campbell, Hamilton.

This table is placed in a line with and in front of the jigging screen, and is 40ft. long by 4ft. wide, mounted on rolled wrought iron beams, I, section, 8in. deep by 6in. broad. The plates forming the table are 8½in. broad, and are fitted to a long linked chain, and are of best mild steel, and pass around two octagonal drums, one at each end; the shaft of the one at the landing end is fitted with a spur wheel. These drums are pitched to suit the chains, and have snugs cast on to prevent any side play of the chains. The plummer blocks at the end of the table next the jigger are fitted with tension screws for regulating the tightness of the chains.

The sides of the table are formed of angle iron, 6in. by 3in. by $\frac{5}{16}$in., with three recesses cut out on each side 4ft. long, and fitted with plates projecting 1ft. 9in. from the sides of the table. These plates are fixed to the angle iron by fish plates, supported by two malleable iron stays, 4½in. by ½in., and fixed to the I beams.

There are six boys employed in the actual cleaning of the coal, one stationed in the space between each two projecting plates, picking out the stones, and should he find any pieces of coal with stone adhering, he immediately rolls the pieces on to one of these plates where it can be perfectly cleaned without in any way impeding the progress of the table.

The coal is landed from the table on two plates, one of which is fixed and the other movable. The fixed part is 4ft. square, with sides 9in. deep, and made of ¼in. steel plate and

angle rivetted together and circled. The movable part is 4ft. by 3½ft., with sides 9in. deep, and also circled so as to prevent the coal falling too rapidly into the waggons. This plate is fitted with four hinges, two pulleys, two levers, and one long lever, with back balance weight and other appliances necessary to make it movable; and it can be lowered to allow the coal a short fall into the waggons when empty, and raised to fit the waggons when nearly full.

One man is stationed in the waggon to trim the coal and otherwise attend to the proper landing of it into the waggon. He has full control of the picking table, which he can throw out of gear at will—should anything happen to necessitate it—by a clutch arrangement.

The table moves forward at the rate of 80ft. per minute, but this speed can be increased or decreased according to the quantity of coal required to pass over it.

The framing for carrying the picking table is wholly composed of malleable iron rails, weighing 75lbs. per yard, cut to proper lengths, two together fitted into cast iron blocks at top and bottom, made for the purpose. The bottom blocks are set on brick foundations, and bolted thereto. The top blocks are of the same construction, but in this case the rails project six inches through. To prevent the top block from slipping down, a binding bolt is inserted through the block.

The cross beams are also rails set on edge, cut to lengths. They are placed close to the projecting part of the upright to prevent them turning, and are tied together with glands.

HYNDSHAW PIT, NEAR CARLUKE.

MR THOS. J. LINDSAY, manager for the Shotts Iron Company at this colliery, supplies the following description :—

The hutches hold about 8 cwts., and from these the delivery is into a shoot 10ft. × 4ft., lying at an angle of about 23°, at which gradient the coals just move when the plate is clear. From this the delivery is on the jigger, which is about 13ft. × 4ft. (dumb plate 3ft., meshing 7ft., and shoot 3ft.), and lying at an angle of about 12°. Fastened to the dumb plate, and at the entrance to the meshing, is placed a cataract plate about 8ins. in breadth, which is raised so as to give the coal a drop of about 2½ins. on the meshing, just sufficient to turn it over, so as to free the lumps from any dross lying on them. This plate also helps to regulate the run of the coal on to the meshing. The jigger is hung upon four ash planks. The delivery from it is upon a table 30ft. × 4ft., running at right angles, at which four boys are employed rods. The coal being soft necessitates a screen at the end of the table, which is 4ft. × 4ft., and lies at an angle of about 24°. The coal passes on from that to a balanced table or plate, from which it is let down into the waggon as required. A set of elevators is used to lift the dross from this screen to make nuts of it. At first it was found that the coal came on to the table in a heap and could not be properly picked. To right this, a plate was hung at the foot of the first shoot, and by means of this the quantity of coal passing to the jigger can be regulated. The engine driving the jigger and table is 7ins. × 12ins., and goes about 120 strokes a minute. The driving shaft of the jigger is coupled to that of the engine, and fitted with two eccentrics, which gives the jigger a stroke of 5 inches. The table is driven off the same shaft with bevel wheel and pinion and chain pulleys. The above arrangement passes about two hutches per minute.

The mesh is made of steel wire warped to a malleable iron frame, the holes being square. This prevents large thin pieces of coal passing into the dross.

GENERAL CONCLUSIONS.

THE methods and appliances in use in any one district can seldom be adopted as a whole in a similar form in another. This applies in many instances to collieries in the same district, and even to different seams worked by the same shaft. The nature of the coal, the associated and interbedded strata, the skill, customs, and prejudices of workmen, the markets to be supplied, the varying requirements of competition, and the caprice of the public, have all to be taken into account when designing plant for classifying and cleaning coal.

While coal with marked characteristics can with care be selected underground so as to be filled separately, no process can be profitably applied underground for effectually removing refuse, especially the smaller particles. To clean coal properly, it must be treated on the surface.

As a considerable percentage of dross is made in transit from the cage to the railway waggon, it is evident that the best results are got where attention is paid to the form of hutch and tumbler, the inclination of screens, and the drop into waggons; and this is specially important in the case of soft coals. A number of contrivances to lessen breakage are mentioned in the report. The careful hand-packing of large coal into the waggons, as practised in the Nottingham district, has advantages.

For effective screening, especially when a large output has to be dealt with, there appears to be no better contrivance than the single or double jigger, or shaking screen, going at from 90 to 100 strokes per minute, and having an inclination suited to the class of coal to be dealt with. There is a preference for wire-meshing for such screens at some collieries, and at others bars or perforated plates are preferred.

For picking, the shaking screen just referred to, or the travelling band, or both combined, is the most effective and economical—the band being about 4 feet wide, 40 to 60 feet long,

and moving at a speed of from 30 to 60 feet per minute, according to the quantity of coal to be passed. Ample length of band allows large coal to be sized and loaded into separate waggons by hand with despatch and economy.

In every case it is necessary that the coal be delivered regularly from the tip hopper to the jigger or travelling band. This can be accomplished by regulating sluices worked by an attendant, or automatically by the intervention of a slow-motion band.

Good light is essential to efficient picking.

A rough rule for deciding the number and length of picking tables may be stated as follows:—One picking tablé for every 30 tons per hour of triping output, travelling at the rate of 40 feet per minute, and having an effective length of 10 feet for every 3 per cent. of material to be picked off, *plus* 15 feet.

The cost for labour of this system may be taken at about 1½d to 2d per ton of round coal for every 5 per cent. of material picked out of that coal.

For round coal, say above 1½in. cube, the dry process is universally employed, and this process can be successfully applied to nuts from say ¾in. upwards where the refuse does not exceed 2 to 3, or even 4 per cent.; and the table capacity required, judging from the examples in the report, is about one table for every 20 tons per hour, travelling at the rate of 30 feet per minute, and having an effective length of 15 feet for every 1½ per cent. of material picked off. The cost for labour will probably be from ¾d to 1¼d for every 1 per cent. picked off. Balanced screens, on which the coal is picked, are available only when the amount of material to be picked off is very small, say 1 to 1½ per cent. For all small under ¾ inch, and for dross from 1½ inch downwards, with more refuse than from 2 to 4 per cent., the wet process is most applicable.

In the wet process it is desirable to have the arrangement so that the small coal can be delivered direct from the screens into the washing tanks without the intervention of waggons. In all the systems of washing, the best results are obtained by sizing the small coal before it reaches the machine. This can most conveniently be done by passing it through revolving screens with meshes of varying size. The supply and

degree of pulsation or agitation of the water require careful adjustment to suit the various sizes of coal to be treated, and the relative specific gravity of coal and impurities.

To remove the refuse from the smaller sizes, say under ⅜ inch, the felspar washer is the most effective. The felspar system is most valuable where the coal is crushed before washing and is to be used for coke making.

Where the coal and the refuse approach one another in specific gravity, it appears that in some cases the trough washer gives the best results. It is applicable for small quantities only, and requires a large flow of water and extra labour, but it has the recommendation of simplicity and small capital cost. It may also be sometimes utilized as a means of transport where the distance from the pit to the waggons or coke ovens is considerable.

The Robinson washer is cheap as regards first cost and upkeep, and requires little water. It largely depends for its efficiency on the attention and skill of the man in charge, who may often be tempted to pass more through it than it can effectually clean.

Speaking generally, more elaborate machinery is effective in avoiding waste in proportion to its cost; but the capital charges and upkeep are also high in proportion.

Other things being equal, coal will be washed best with an abundant supply of clean water; but the more water used, the greater the risk of fine coal being lost, and the greater the difficulty of filtration. Water to wash coal for coking should not be often used over again, as dirty water dulls the coke.

The particulars furnished as to settling ponds do not give sufficient data to justify any definite conclusion as to their capacity in relation to the quantity of coal washed. In most cases no record was kept of the quantity of water used; but settling ponds are a necessity, and their capacity will depend on the special circumstances of each case.

There seems no better way of filtering the foul water, after it has passed through the settling ponds, than pumping it on to the rubbish heap, and allowing it to percolate through, as at Earnock.

The washed gum of coal not suited for coking is meantime

used almost entirely for firing colliery boilers. Briquettes are made of it to a small extent, but new outlets are required for this product.

The large quantity to be treated daily, and the varying nature and proportions of the coal and dirt to be separated, render washing, at most collieries, a troublesome process; and unqualified satisfaction is seldom expressed as regards any machine in use. In some cases the machine may not be quite adapted to the peculiarities of the coal treated, or it may be overdriven, or not have a sufficiency of water, or be allowed to get out of repair, all or any of these causes leading to disappointment as to results.

A separate siding for each class of coal is a desirable arrangement.

While the investigations of the committee have not led them to prefer and recommend any particular system as the best in all circumstances, the examples given will, it is hoped, be valuable in directing attention to the conditions in which each system reported on is likely to be most successful and profitable, leaving it to individual skill and judgment to adapt and modify as special circumstances may require.

Reported by

JAMES BARROWMAN.
CHARLES CARLOW.
DAVID COWAN.
JAMES S. DIXON.
JAMES GILCHRIST.
A. M. GRANT.
JONATHAN HYSLOP.
DAVID M. MOWAT.
SAMUEL POTTS.
JOHN SMITH.
WALLACE THORNEYCROFT.

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THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

HALL OF THE INSTITUTE, HAMILTON,

21st November, 1889.

JOHN M. RONALDSON, Esq., President, in the Chair.

The minutes of the last General Meeting were read by the Secretary, and confirmed.

The following were elected by ballot as ordinary members:—

W. T. Bowie, Royal Exchange, Glasgow.
Edmund Plunkett, Punjom Gold Mines, Singapore.
R. P. Roy, Carron Works, Falkirk.
John Baird, Cleveland Cottage, Loanhead.

The following discussions then took place :—

DISCUSSION OF MR F. J. ROWAN'S PAPER ON "GAS-FIRED BOILERS."

The SECRETARY read the following communication from Mr Rowan:—

I regret that the absence of railway communication at a suitable hour prevents my being present at the meeting of the Institute, and that the special reason for my absence from the last meeting, when my paper was under discussion, was evidently not communicated to the meeting. I would have been present on that occasion had it been at all possible, and I am glad to have the opportunity of replying to the remarks made in the discussion which was eminently practical and to the point.

The President's enquiry raises the wide question of the suitability of gas firing to different operations, and in replying to it I must first of all emphasize the remark that *it is a mistake to make economy of fuel, the only, or even the major, consideration in connection with this subject.* Several other elements enter into a *thorough* consideration of the matter, and these will have more weight as acquaintance with the subject is spread.

It is undoubtedly the fact that the superiority of the gaseous form of fuel becomes more apparent as the temperatures which are to be produced become higher. The intense heat of melting steel or of welding iron can be maintained by direct firing with solid fuel, only by an enormous expenditure of the best lump coal, accompanied by great waste of heat energy, waste of metal by oxidation, wear of furnaces, labour, and vitiation of the atmosphere by smoke and great quantities of noxious gases. The use of gaseous fuel has made it easy to work methods of intercepting and returning to the furnace a very large proportion of the heat which is carried off by the waste gases escaping, as they must, from the furnace at the high temperature produced therein. With gaseous fuel the excess of air admitted above the quantity theoretically required for combustion is enormously reduced, oxidation and waste of metal are prevented, labour are lessened, the life of furnaces prolonged, and a reduced quantity of fuel of a very much lower grade suffices to do all the work.

Consequently, for all high temperature operations, the use of

gas fuel is all but universal. No one, for instance, would think nowadays of putting down a steel work without gas producers.

In dealing with boiler firing—and evaporating generally—we have a comparatively low temperature operation to consider, and one, therefore, which is better within the reach of ordinary direct firing with solid coal. Not only is the quantity of heat escaping in the waste gases much smaller on this account, but it is still further reduced by the fact that the heat produced by combustion, and carried by the products of combustion, is continually absorbed by the boiler "heating surface" from the moment of combustion to that of exit to the chimney. There is thus comparatively little heat to conserve. It is manifest that the larger the proportion of heating surface to grate surface, the more completely is it possible to utilize the heat derived from the fire; and the boilers used in Mr Cowan's experiments are of a kind to demonstrate this point very completely. Moreover, the nature of this heating operation is such that the radiant heat from a solid coal fire is peculiarly applicable, as I have pointed out in the paper, while, at the same time, by carefully and intelligently conducting the hand stoking, loss of heat, by means of excess of air, and by fluctuations of temperature, may be confined to moderate limits.

One reason, therefore, why gas firing has not yet been more largely introduced for boiler firing is that, even in favourable circumstances, the percentage of saving of fuel possible is not anything like so large as in other firing operations, and, moreover, that saving can only be effected in fuel of the lowest grade, viz., dross. In the case of collieries where dross is sometimes unsaleable, it will readily be understood that, *on the score of money saving in that fuel*, a case for firing the boilers by gas can be made out only with some difficulty!

In the case of works where, on account of the cost of carriage of fuel, a higher quality is used, or in circumstances such as those mentioned by Mr Johnstone at last meeting, gas firing may be introduced with advantage in view simply of a money saving in fuel, because the work can be done with a lower quality, and the difference will often pay a return even on the cost of altering existing arrangements. Where owners of boilers have to consider

the *alteration* of arrangements for firing, there is the question of the attendant expense to be dealt with, and there is no doubt that, especially in this country, outlay, or first cost, is usually kept low, even although working expenses are thereby slightly increased. I do not discuss the economics of this plan, but as a general rule I do not believe in it. Where new boilere are installed, even at collieries, there are several points that make gas firing worth considering, apart from the question of saving in fuel. These are—1, Saving of labour in stoking and in cleaning boiler surfaces and flues; 2, Saving in wear and tear of boilers and in repairs; and 3, Smoke prevention, which in the neighbourhood of large towns means immunity from prosecutions and fines—not to speak of the sanitary and philanthropic aspects of the question. It is impossible to put down a money equivalent for these advantages which would be universally applicable, and, consequently, they are usually ignored; but nevertheless there are some men who recognise that there are important matters which it might be difficult to express in terms of money.

In large works, as Mr Cowan has remarked, there is also the question of concentrating the fuel supply, and diminishing labour in distributing it and in removing ashes.

Mr Cowan has, however, put the matter in a false light by speaking of gas firing in the light of a "universal specific for all evils." It is no question of finding a specific for evils, but of the intelligent adoption of the very best means of attaining the end we have in view. The discussion at Paris, to which he referred, was mainly as to the value of *water-gas* for ordinary operations, and, therefore, considered as a discussion as to the best means of applying fuel, was a one-sided and worthless affair, comparatively speaking. Very few men in their sober senses would think of generating water gas for the purpose of firing boilers or ordinary furnaces, although it, no doubt, would suit some special people to do so.

In further reply to the President, I would say that no difficulty with the working of gas producers stands in the way—their construction and working are too well understood to permit of that nowadays, except in isolated cases. At the same time, I must repeat that *no one form of gas producer will answer for all*

descriptions of fuel. Coal-dust, or the refuse from coal-washing machines, could not be used in producers which would answer quite well with ordinary unwashed dross, and large coal, again, would require a different form and method of working.

With reference to the figures of cost of applying gas firing to boilers, as the estimates named by Mr Gilchrist were given by me, I should like to say that they included patent royalty, and were otherwise rather high. For some time I have been building producers clear of any patent, and in this way I have succeeded in lowering their cost. Even at the present time, when prices have greatly advanced, I do not think the figures he gave need be much exceeded for equipping six boilers, even although in a case of altering existing arrangements.

The experiment with gas firing applied to Babcock & Wilcox boilers, mentioned by Mr Cowan, appears to be adverse to the use of gas for such a purpose; but as we have no particulars of the manner in which the gas was produced or applied to the boilers, we are unable to judge whether the result mentioned was a proper one or not under the circumstances.

The means used for *applying* the gas—that is, for effecting its combustion in the best way in given circumstances—*require as careful adaptation to the apparatus or furnace which is to be heated, as the form of producer does to the fuel which is to be gasified in it.* To inattention to these principles, or faulty arrangements, is due frequently failure to obtain the best results.

Mr HUGH JOHNSTONE said that in his remarks on p. 133, he took exception to the estimate Mr Gilchrist gave as to the cost of erecting a gas firing plant. That exception was taken under a misapprehension of Mr Gilchrist's figures. He thought that he stated that the cost was about £400 per boiler, whereas he had found it was £250 per boiler. He merely wished to say this was not above the cost in his experience; if anything, it was rather below it. Mr Gilchrist's estimate was a very moderate one.

The PRESIDENT said they were all indebted to Mr Rowan for his admirable paper. It must have given him great labour to get it up, but the subject seemed to be specially in his line, and the preparation of the paper a labour of love. There was one phase of gas firing that was most desirable, viz., its application to do-

mestic purposes in large towns such as Glasgow. He thought the housewives would be grateful to the man who would introduce a plan by which they could abolish the use of solid fuel, so that all they would require to do, in their household operations, would be to turn off and on a gas stop-cock as they required it. There would be no dust and smoke, and there would be a saving in many ways. Then, again, if this were done they would not require illuminating gas for lighting purposes, for by such a system as the Welsbach, in which a brilliant light is obtained by a Bunsen burner heating to incandescence a framework of certain constituents placed above it, producer gas would be available, and they would get the lighting of their houses done much more economically. In many other ways such an innovation would be very much to be desired, and he was not opposed to seeing something of that sort attempted on a large scale. He asked them to accord a hearty vote of thanks to Mr Rowan for his paper. (Applause.)

DISCUSSION OF MR ANDREWS'S PAPER ON "AIR VESSELS."

The PRESIDENT, as Mr Andrews, in the belief that the discussion was to be continued, had sent no reply, suggested, if there was nothing further to say, that they should leave the matter open for the reply.

This was agreed to.

DISCUSSION ON MR SMITH'S PAPER ON "LIGHTNING ENTERING DRUMSMUDDEN PIT WORKINGS."

The SECRETARY read the following communication from Mr J. B. Dalzell :—

The details regarding the lightning which passed down the pumping pit and along the dook in Drumsmudden Colliery possess some points of interest intimately related to an occurrence that happened several years ago in Italy. Minute particulars of it have been given by Father Secchi, the able director of the Observatory of the Roman College. In both instances, the lightning followed a traceable course underground, ran along water-pipes, and at points of its progress emitted light, thus favouring the possibility of a thunderstorm effecting an explosion of gas in pits.

During the night of 2nd November, 1872, a violent storm broke over the town of Alatri in Italy, the Cathedral of which was struck thrice by lightning. The first and second discharge did no damage, but the third, after fusing more than an inch of the lightning conductor—affecting the screw so much that it could not be unscrewed without breaking—and stripping off the gilding, passed into the ground, and produced the following remarkable results :—

About 11 yards from the base end of the conductor stood a house, from which proceeded two cast-iron pipes conveying the water supply of Alatri and Ferentino. These pipes were not connected with the conductor. To this house the lightning ploughed a trench, in a straight line, over two feet deep, throwing the earth out neatly on either side. It pierced a hole through the wall, damaging the corners of the building; entered the nearest pipe (the Ferentino one, 28 inches in diameter), bursting it, fusing the leaden joints, flooding the house with water, and then passed out along the pipe towards Ferentino. A less powerful current—apparently the surplus electricity only—took the further pipe, and on the way to Alatri it passed a reservoir, flinging to a distance some wooden plugs that had been driven into the reservoir. In Alatri itself the pipe discharges into another reservoir situated between 600 and 700 feet distant from the Cathedral.

Into this reservoir the electricity entered, and after bulging out a sheet of lead badly, it passed on, doing damage of minor consequence on the route. It finally escaped by the outlet pipe of a public fountain, after having traversed a total distance of nearly a thousand feet.

At various points in its track the lack of sufficient conductibility manifestly occasioned a rise in temperature, and, inferentially, flame similar to that seen by the workmen at Swinhill and Drumsmudden Collieries. These points were :—(1) The fusion of the point of the conductor till it was a centimetre in diameter ; (2) The enlarging of the screw ; (3) The stripping off of the gilding ; (4) The formation of the trench by the instantaneous heating of the dampness of the soil into steam, just as the tree is split into ribands by the lightning flash ; (5) The piercing of the wall of the house ; (6) The bursting of the Ferentino pipe and fusion of the leaden jointing ere the excess of electricity had found an outlet by the Alatri pipe ; and (7) In the two reservoirs, by the blowing out of the plugs and the distortion of the sheet of lead, the cause in both being the instantaneous conversion of water into steam.

From the experience of Father Secchi, it would seem quite possible that a part of the very electricity that "uplifted the earth and ashes" at the bottom of the boiler stalk, made for the pumping pit only ten yards off, and, descending the pipes, joined at the pit bottom with the current that must have run down the two haulage ropes.

Two conclusions appear to be warranted by the details of the occurrences at Swinhill, Drumsmudden, and Alatri, and, probably, at Risca Colliery and Hexham as well. One is that the base of a lightning conductor should be more than ten or eleven yards from a pit shaft, more particularly a shaft in which there are metal guides, pipes, or wire ropes. The other is that it should be obligatory on owners of fiery mines to fit up a proper lightning conductor upon the pithead frame of each shaft in which wire ropes are in use, or at which the pithead frame is of metal.

The PRESIDENT said this was another illustration of the danger that arose in connection with fiery pits. He did not see how they were to keep the lightning out of their pits unless by

proper conductors. He thought Mr Dalzell was right in what he proposed as to a lightning conductor, because there were lightning conductors and lightning conductors. He had known one fitted on a chimney with the lower end merely touching the ground. Well, he supposed it would be better without it. It was well known to scientific men how they should be fixed, and he thought that was a very simple matter to get over. He proposed a vote of thanks to Mr Smith for his interesting contribution to their Transactions. (Applause.)

The Secretary submitted the Report of the Coal Cleaning Committee, which appears on pp. 145-231, illustrated by Plates VIII. to XLII.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,

26th December, 1889.

Mr JAMES HASTIE, Vice-President, in the Chair.

The minutes of the last General Meeting were read by the Secretary, and confirmed.

The following gentlemen were elected by ballot as ordinary members:—

Mr BRYDONE, Wellington Collieries, Nanaims, British Columbia.
HENRY BEATON, Balbardie Colliery, Bathgate.
JOHN B. WINGATE, 208 St. Vincent Street, Glasgow.

The following discussions then took place:—

The SECRETARY read the following reply by Mr Andrews in the discussion of his paper on "Air Vessels":—

It will not be out of place, I presume, on my part, if I now offer a few observations on the criticisms which were made on my paper on "Air Vessels." And here let me frankly admit that I have made a slight error, for which nobody can be more sorry than I am, in calculating the excess of pressure which would accrue by pumping a full stroke of the plunger into an air vessel under the circumstances described in my paper. The excess of pressure is, as Mr Easton puts it, 45·8. The error arose, not from any desire to mislead, nor by any fault in the method of calculating—for our methods are precisely the same—but merely through inadvertence in not checking the figures. Fortunately the error is of little moment, so far as the argument is concerned.

My argument was to show the insignificant effect that air vessels in general use had in counteracting *vis inertia*, and the palpable effect they would have, if of sufficient dimensions and properly tended. In this connection I endeavoured to prove that, with an air vessel four times the capacity of the plunger, and charged with air in the usual way—that is, by emptying the column—before the air vessel could make room to hold even *one-tenth* of a stroke of the plunger, the pressure would be increased from *260* to *520lbs.*; whereas, with the air vessel which I assumed properly charged, it would hold a *whole stroke* of the pump, and the pressure would be increased only from *260* to *297*. That is, in the one case, in order to hold 10% of the stroke of the pump, the pressure is increased 100%; whereas, in the other case, in order to hold 100% of the stroke of the pump, the pressure is increased only 14·2%, or, when corrected, 17·6%. The balance in favour of the latter is so great that I can well afford to throw in the odd 3·4%, and still leave a large margin in favour of the size of air vessel and method of charging recommended in the paper.

Thus far I have been able to follow Mr Easton. I am sorry that we must now part company. In his extravagant calculations as to the dimensions and weight of an air vessel ten times the capacity of a plunger pump, of which he has charge, I cannot follow him. The diameter of the plunger, it seems, is 28″, and

the length of stroke 6 feet. It would have been interesting if he had informed us at the same time whether the pump was wrought by a direct-acting engine, or by a geared engine with a fly-wheel, and the depth of the lift as well. If, by a direct-acting engine, with the weight of the rods forcing up the water, my contention is that such pumps have no need of an air vessel. No doubt Mr Dugald Baird contends that a direct-acting engine has need for an air vessel, and even goes the length of saying that an engine and pumps of that class have more need for an air vessel than one with a fly-wheel, for the reason, as he explains, "that when a direct-acting engine comes on air, the ram having nothing to support it at the top stroke, immediately the steam leaves the under side of the piston it will fall with the full force of gravity on the heavy rods, and strike the water much harder than if the engine was a rotary one, because, in that case, the *inertia* of the fly-wheel and the rest of the machinery would retard the blow."

None of the speakers ventured to say that a direct-acting engine required an air vessel unless when the pumps came upon air. I may, therefore, assume that they agree with me that so long as the pumps are on solid water there is no need for an air vessel. My reply, then, is: Arrange matters so that the pumps cannot come upon air. If any of you have an engine of the direct-acting class, and have had trouble with the pumps coming on air, I will very gladly undertake, at very little expense, to arrange matters so that before the pumps can come upon air the engine will infallibly stop.

But to return to Mr Easton and his 50-ton air vessel. True I stated that for a vertical rising main the air vessel with an internal pipe is, perhaps, as good as any. I hope Mr Easton did not infer from that statement that I recommended an air vessel of that class whether the pit could hold it or not. Air vessels, like everything else, have to be adapted to existing circumstances. When these circumstances are such as to render an air vessel of a certain class impossible, we must then look out for some other kind that is possible, and not only possible but practicable, and the best of its kind under the circumstances. Until Stephenson's day, the Cornish boiler with its single furnace and flue, the Lancashire boiler with its double boiler and flues, and the Marine

boiler with its serpentine flues, were the best steam generators known. It would, therefore, have been quite legitimate for any engineer of that day to declare that no boiler of any of these classes would be safe with 100 lbs. pressure, and even if it could be made safe, it would be such an enormous size and weight that no road could carry it; therefore, locomotion on a railway by steam was absurd.

I would, therefore, impress upon Mr Easton that my statement was qualified with a "perhaps," that there are other positions for an air vessel than the shaft, that there are even other positions than the vertical, that there are other means of connecting than the internal pipe, that there are other materials than cast iron of which an air vessel can be made, and that it does not follow because Mr Easton's rising main is $2\frac{1}{2}''$ thick, that $2\frac{1}{2}''$ is the precise thickness that would withstand the pressure, and that, therefore, his hypothetical air vessel, $77''$ dia., must be $8\frac{3}{4}''$ thick. Mr Easton has not given us the depth from which his pump discharges the water. I will suppose it is 100 fathoms, and there are few pits in Scotland where even 100 fathoms is delivered with one lift. The statical pressure due to 100 fathoms is 260 lbs. per square inch, the rising main is $27''$ diameter outside, and $27'' - (2\frac{1}{2}'' \times 2) = 22''$ inside. Now, let P represent the pressure, D the internal diameter, and T the thickness of metal, the strain per square inch in the direction of bursting the tube will be $\frac{P \times D}{T \times 2} = 1144$ lbs. per square inch of tensile strain. But I find as the result of ordnance experiments on 51 samples of cast iron, that the average tensile breaking strain was 23,257 lbs., which is fully *20 times more* than the statical pressure could exert to burst Mr Easton's pipes. I think, then, you will agree with me that his 50-ton air vessel will be sadly diminished in weight, and that to make 22in. pipes $2\frac{1}{2}$in. thick even to deliver 100 fathoms is the height of extravagance.

But I have already said that there are other materials than cast iron of which to make an air vessel, and other positions in which to place it than the vertical, and there are methods of connecting other than the internal pipe. It would be absurd to put on the rising main in a shaft an air vessel with an internal pipe,

of which the annular space was ten times the capacity of a 28in. ram, with a 6ft. stroke. We must therefore resort to some other way of it.

Under such circumstances I would suggest that the air vessel be mild steel, 22ft. long by 4ft. dia, hemispherical end, ¾in. plates, laid horizontally in a place cut out of the rock for the purpose; a separate connection for inlet and outlet, and both placed as near the bottom as they can be got. Such an air vessel would be ten times the capacity of a stroke of the pump; it would be ample strength for a statical pressure of 260lbs.; it would be equally serviceable for an air vessel as if placed on end, and instead of weighing 50 tons it would weigh 4½ tons. I would, by adopting an air vessel of this description, be relieved of the necessity of devising a scheme for putting an air vessel weighing 50 tons in position, and would have an air vessel at a cost not exceeding £100, instead of Mr Easton's hypothetical monster, at a cost of £500.

Mr Easton has very kindly explained to us the meaning of "this mysterious-looking term, *vis inertia*," but I am sorry to observe that his definition, so far from being instructive, is rather misleading. So long as Mr Easton confines his explanation to a rising column his explanation is quite correct, for the pressure in that case is just the measure of the height of the column, and therefore the measure of the *weight* of the water to be moved. The weight of the water in a vertical column and the pressure being thus convertible terms, either may be taken indiscriminately as the first factor in the calculation of *vis inertia*. The other factors are as he puts them. But a rule, to be a rule, must apply in every case, unless the limitations are expressed in the rule. No such limitations being expressed, the rule must be taken as universal.

I will now endeavour to explain how this rule of pressure, as a factor, would work in a discharge pipe other than vertical; show the fallacy of taking pressure as a factor, prove that pressure has no relation to *vis inertia*, and that *weight* as a first factor is true under every conceivable circumstance. Suppose, then, I take (1) a vertical column of 100 fathoms, having a statical pressure of 260lbs., and (2) I will take a dook discharge pipe, 200 yards in

length, laid on an incline of 1 in 10, equal a vertical lift of 10 fathoms, and a statical pressure of 26lbs., and I will suppose the plungers are the same diameter and length of stroke, the number of strokes the same, and the discharge pipes the same. The diameter and length of pipes being the same the weight of water in the pipes must be the same. In short, everything is the same except the pressure. Now, according to Mr Easton's rule, the *vis inertia* of No. 1 column will be ten times that of No. 2, because it has two times the pressure; but according to all the laws of bodies in motion, the *vis inertia* is exactly the same. The same weight of water in both instances have been changed from a state of rest to a state of motion, at the same speed and in the same time, the measure of which is just *vis inertia*.

Another illustration. There is a dook 1200 yards in length with a declivity of 1 in 5, consequently, a vertical depth of $\frac{1200}{5} = 240$ yards $= 120$ fathoms. Near the bottom of the dook is placed a 14in. double-acting plunger pump, on the "Moore" principle, being actuated by a 7in. pressure pump (No. 1), and it again actuated by a pressure pump (No. 2), wrought by an engiue. The pump No. 2 and the engine which works it are both within a few yards of the pit bottom, and consequently about 1200 yards from pump No. 1. The pressure pumps are connected by a 4in. pipe under a pressure of about 1400 lbs. to the square inch. Pressure pipe No. 1 is about three times the area of the 4in. connecting pipe, and I will suppose goes at the rate of 50 feet per minute each way; consequently the water in the pressure pipe will travel at the rate of 150 feet per minute, and must stop and start with every stroke of the pumps. If Mr Easton's theory were to hold good, that the pressure in the 4in. pipe was a factor in calculating the *vis inertia*, said *vis inertia* would be almost irresistible, and Messrs Moore might bid good-bye to the success of their pump. Fortunately, however, for the "Moore" pump, the pressure which conveys the power is not a factor in the calculation, the only factors being the *weight* of the water in the power pipes, the suddenness and speed of the change from rest to motion, and from motion to rest. Indeed, the water in the pressure pipe may just be considered as a pump rod, and it would be as rational to take into

consideration when calculating the *vis inertia* of a pump rod, to take into account the power the rod was transmitting, as to take into account the *pressure* in the power pipe, which, with exception of the *weight* of the water in the pipe, is just the measure of the power transmitted.

Weight, then, being a universal factor in calculating *vis inertia*, and always right, and pressure being a factor only when it is the measure of a vertical head of water, which is just another way of giving the weight of water, and erroneous in every other connection, it is, therefore, quite correct to say that pressure, as pressure, has no relation to *vis inertia*.

Mr Easton's communication having embraced nearly the whole substance of my paper, and my reply to his strictures being also applicable to most of the remarks made by other speakers, I am, therefore, left with little more to say. Mr Mowat, I observe, has doubts as to the propriety of admitting air to the pump by means of a small pet cock on the suction. On the other hand, one of the speakers at the discussion on Mr Baird's paper stated, as the result of his experience, that a little air admitted at the suction caused the pump to work more smoothly, an opinion in which I entirely agree. See my remarks near the bottom of page 116. I fear Mr Mowat has been admitting air in too great quantity. He may rest assured that admitting air in such fashion is past the stage of experiment. I have seen it and practised it often, and when done judiciously, invariably with good results.

And now, in conclusion, I have to express my unfeigned thanks for the kind and considerate manner in which my contribution was received, and for the temperate—I might almost say the complimentary—tone which characterised the discussion.

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DISCUSSION OF THE COMMITTEE'S REPORT ON COAL CLEANING.

Mr RALPH MOORE said he presumed in such an important paper as this they would have two or three nights' discussion. He got his copy some days ago, but he had scarcely got begun to read it. It was a paper that required very great consideration, and would repay many times' reading. He was in America not long since, and had seen a plan for separating stones, from gold, which was quite the reverse of a coal cleaning machine, because the gold had to be retained and the other rejected. Mr Moore having described the machine on the black board, said it occurred to him that coals might be cleaned in the same way. He was promised a drawing of the machine, and if he got it he would give it to the Institnte. He should like to say further, that during a very extensive tour amongst the collieries in America and Canada he did not see many things very new. The cleaning arrangements at one place, where they separated nuts, was simply a shaking screen, and they had no tables. They had, however, a machine for breaking the coals into different sizes, especially in the anthracite districts. In the anthracite districts, the large coal, ten or twelve inches in size, was of no use for household purposes. The large coal could only be used for making iron, and what was not used for making iron was brought back to the trigger, which consisted of revolving teeth, which broke up the coals. They were then sold into various kinds—nuts, eggs, and so on, the largest piece being about three inches square, and eggs two inches square. Then came a smaller size, whlch were called beans, and a size smaller still. These small coals were most useful in the stoves which were in common use in America. These were fed from the top, the air being admitted from below, and it was only at the opening where the air was admitted that there was any flame. They would, accordingly, see that it would not do for large coals to be put on these stoves. The rule was for coal of about an inch diameter to give the highest price, because it was so useful. It was just what was now being introduced in

Scotland—the making of nuts and other grades of small coal, but the Americans had been in the habit of doing that during the last forty years. Before the apparatus now in use was introduced they broke the coal with hammers. If the people could be educated to the point of using coal of two or three inches it would be a good thing for the coalmasters.

Mr JOHN DRINNAN said Mr Moore had raised a point in his remarks, to which, for some considerable time, he had attached some importance, viz., the question of small coal. A year or two ago, he noticed some reference to that in the "Colliery Guardian," the statement being made that small coal was in much demand in France, and was coming into great demand in Germany. He knew also that, in the Midlands, where he was recently, small coal was in very great demand for London, in the shape of what were called "London Brights." It was a class of coal they never could get enough of to supply the demand, and, in consequence, some of the collieries—the one he was connected with, and others—to a considerable extent broke up the best coal for this purpose. Prior to that, what they sold as such might be said to be inferior—that was to say, the best coal of all classes was picked off the table and passed over the screen, and the large and small nuts taken out. It was a little bit larger than large nuts. When one came to think of the purpose for which these were used, they could hardly wonder that a demand should commence to exist. Indeed, he was inclined to wonder it had not sprung up sooner, because coal, in such cases, had to be carried up a considerable number of stairs and put into bunkers. Accordingly, it seemed an absurdity to have to carry and break it up there, because of the dross thereby made. It must be very much more convenient and economical to get the coal just in such pieces as were handy for taking it from the bunker and putting it on the fire. That was one of the questions which, he thought, would have been likely to be forced on the Committee who had been engaged in making up this report, and he had been somewhat surprised to see that it was omitted from the report. But it might be that, if they gave close attention to the report, a great many of them might be forced to believe that there was a much more profitable future for small than for

large coal; and, if it benefited them in that way to the extent of causing them to make provision for it before being out-distanced by their neighbours, then the labours of the Committee would not be in vain.

Mr ALEX. FAULDS said he might mention a few things he had noticed in looking over the report. At p. 148 it was said "The centrifugal pump was working at a speed of 845 revolutions per minute." That seemed to him a high velocity. At p. 149 there seemed to be an error in the last column of the table, which should read "30 cwts. coal per ton of coke." He observed that some of the revolving riddles were conical instead of being placed at an angle, which he thought an improvement. At p. 156 the hutches were said to be 12in. deep. He thought that must be a mistake, and that 2ft. deep would be more nearly correct. Also, at the foot of the same page, the length and width of the screens were given, but not the width between the bars. At p. 166, as to the reference to Plate XIV., he thought it would be interesting to the members if the sort of mechanical arrangements in use were explained. Again at p. 168, as to the washer, he would like to know from the Committee the experience they had had of glass bottoms, the thickness of the glass, and what was the particular object of it. Then, regarding the Cumberland and Newcastle districts, it might be made a little more interesting if the Committee would give information regarding the hutches, if they were made of wood or iron, or both wood and iron, or wood and steel; the weight of each hutch, and the weight of the load. Some of the members have had considerable experience with picking tables, and he saw a number in England similar to those in use in Scotland.

Mr RALPH MOORE said, with regard to cleaning tables, he had been always under the impression that Mr Thomas Whitelaw was the first to put up picking tables in Scotland, and that he was really the inventor of it.

Mr FORGIE confirmed this.

Mr FAULDS said Mr Whitelaw had a royalty paid to him for some considerable time.

Mr DRINNAN said perhaps the Committee would be able to answer the question that had presented itself to his mind. After

seeing all the different washers at work, had they not formed any conclusion as to the best class of washer for a particular class of coal?

Mr GILCHRIST said, in regard to page 166, looking to the description of the Plate, he did not see that anything had been omitted. Then as to the glass bottoms, the explanation was they were so much troubled with the former bottoms, which were of wood, wearing quickly, as an experiment they tried glass bottoms. He did not think they took note of the thickness of the glass, but they were told there was no appreciable wear in the glass bottoms. Then, in reference to Mr Drinnan's last question, they saw different washers washing different classes of coal, and it did not seem to them that any one special machine was specially adapted for washing special classes of coal. They would notice the general conclusion was that unqualified satisfaction was seldom expressed as regards any machine in use. As to the arrangement referred to on page 166, he thought that was one of the finest things they had seen, the creeper being adapted for carrying coals in two opposite directions.

Mr FAULDS said that was what he wanted explained. He had seen several. He understood that in a German creeper the dross dropped through the top belt to the bottom one.

Mr GILCHRIST said as to the German creeper, he had seen it, and instead of plates it was made of bars. In breaking the coal and taking anything out, dross was made, which fell through the bars, and the creeper is so arranged that in returning it carried the dross backwards. This was not a creeper of that description. This was one adapted for carrying both ways.

The discussion was adjourned.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

HALL OF THE INSTITUTE, HAMILTON,

30th January, 1890.

JOHN M. RONALDSON, Esq., President, in the Chair.

The minutes of the last General Meeting were read by the Secretary, and confirmed.

The following were elected by ballot as ordinary members:—

WILLIAM ADDIE, Summerlee Iron Works, Coatbridge.
PETER PATERSON, 1 Cambusnethan Street, Wishaw.
JAMES IRVING M'CONNEL, Sanquhar Colliery, Sanquhar.

The following discussion then took place:—

SAN FRANCISCO.

DISCUSSION OF THE COMMITTEE'S REPORT ON COAL CLEANING.

The SECRETARY pointed out that, at p. 212, the thickness of the zinc was stated to be 0·55, whereas it should be ·055. In the description of the trough washing machine at Lodge Colliery, at p. 216, the trough was stated to be 100 feet long. Mr Thomson now stated that, instead of being 100 feet long, it was 60 feet long. He might also refer to a letter which he had from Mr James Mungall, Cuttlehill House, Crossgates, Fife, who was formerly general manager to Messrs James Dunlop & Coy., Newton and Hallside Collieries. Mr Mungall took exception to Mr Dixon's description of the arrangements at Hallside Colliery described on p. 219, and wrote:—"The description of the arrangement of screens at Hallside Colliery, Newton, states these have 'been designed by Mr James S. Dixon, M.E., who furnishes the description and drawings shown on Plate xxxix.' The description goes on to say—'The outstanding feature of the arrangement is the introduction of a slow-moving conveyor, *B*, which arrangement was previously in operation at Newton Colliery, &c.' As this description conveys the idea that the design is Mr Dixon's, it is to this extent misleading. The erection at Hallside is apparently a copy of that designed by me for Newton Colliery some years ago, where the outstanding feature was introduced, first at No. 2 Pit, and subsequently at No. 1 Pit, on the re-construction of the screening arrangements there."

Mr JAMES S. DIXON said he was sorry if there was any one who had taken any other meaning out of his description than was on the face of it. He stated that the arrangement of the pithead and screens was designed by himself, which was the fact, but this "outstanding feature"—he gave it that name because it was a good feature—he said, was previously in use at Newton. By that he meant to convey that it was there before he had any official connection with these collieries. Whoever had the merit of the feature was welcome to the credit of it, and it was a very good one. He had no intention of taking credit for that

feature of the arrangement. He might say, since the screens had been at work, he had seen reason to make two slight alterations. The one was as regards the long shoot from the end of the picking table, which was found not to work satisfactorily. Although it was 1 in 2½, the coal slid down too quickly, and he put in a jigging arrangement, and shook them from the small dross screen into the waggon, which, he thought, would be a great improvement. Then, at the end of the conveyor taking the nuts from the screen to the waggon, he intended to put in a circular riddle instead of the sliding screen, as it was not found to take out the gum as well as desired. He thought, with these improvements, the arrangement would be a very good one indeed. He noticed that Mr Faulds, at last meeting, took exception to the depth of the hutches referred to on p. 156. That was with reference to the report of the screen at the Ebbw Vale Colliery. As he was responsible for that report, he might say this was quite correct. The hutches were of the size given, viz., 4ft. 6ins. by 12ins. deep, and held 19cwts. He never saw hutches so much heaped.

The SECRETARY said he had a letter from Mr James F. Waldie, indicating his disappointment at the Stewart-Waldie Washer not having been referred to by the Committee. He was not aware that the Coal-Cleaning Committee proposed to give a report on every coal washer that had been designed, or was in operation; and, from the fact that that machine had been so recently very fully described by Mr Waldie himself (Trans. Vol. IX., p. 146), and very fully discussed in the Institute, he did not think it was necessary that that machine should be specially taken notice of. Certainly no reference had been made to it in the report, but, on the other hand, there were other machines of importance in the country which had not been described—*e.g.*, Lührig's, of which there were several in operation in Scotland. Mr Waldie might observe on the note of the business of the meeting that descriptions and sketches of appliances not referred to in the Committee's Report were invited, and if Mr Waldie had anything fresh over and above what had already appeared in the Transactions, he had no doubt the Institute would be glad to have any particulars he had to offer.

Mr JOHN DRINNAN, in reference to a statement on pp. 147-148, asked if there were two basins *J*, or if the dirt and the coal were both deposited in the same basin.

Mr DIXON said there was an error there, which would be looked into by next meeting. *J* was the basin for the very small coal.

Mr DRINNAN said, seeing the question of small coal was engrossing some attention just now, his attention had been attracted to the statement on p. 149, bottom paragraph, that 75 per cent. passes through the screen. He thought that a very large proportion of dross, unless the coal was broken purposely.

Mr THORNEYCROFT said the information was correct. The coal was not crushed. It was a thin seam and a soft coal, and the bulk of it was dross.

Information was asked as to the thickness of the Jonah seam, p. 149.

Mr DRINNAN said he had a question as to the cost, as he thought it would be interesting to all who used washers to see what the item for washing stated on p. 150 really meant. The cost was given at ¾d a ton. If this included the three men that were attending the washer, and those engaged in shifting waggons and firing the engines, and any other work that might need to be done in connection with the boilers, it struck him that these men would be insufficient to do all the work, and unless the wages of all the men connected with it were included in the cost stated, it was altogether misleading.

Mr THORNEYCROFT said this statement of cost was just as it was given to the Committee. At the time of the Committee's visit, the machine had not been working more than three days, so this question of cost was purely an estimate. It was Mr Stevenson's estimate.

The PRESIDENT said he was told that dross was getting so valuable that people were thinking of doing away with washing machines, because they now got a better price for it. If things continued at this rate they would not require any washing machines to encourage its sale.

Mr DRINNAN said at p. 166 it was stated that there were three picking tables at the particular place, and it was said they ravelled at the rate of 40 to 50 feet per minute, and dealt with

600 tons of coal in the twenty-four hours. He thought the coal must have been very thinly spread along those tables, or otherwise they must be running a considerable part of the time empty. At least, he knew that at Trowel Moor Colliery, where he was lately, they could send over 350 tons during a three-quarter day, and certainly not going at a greater speed, but more slowly. He was very much struck with the number of hands employed. It seemed to him that all the coal must have been picked out.

Mr JAMES GILCHRIST said, so far as he remembered, the table seemed to be pretty well taken up with coal, but round coal only was picked at one of the tables; the nut coal and peas were picked on the other two tables. What struck him was that the nut tables were very much crowded, far more so than the coal tables. They had every facility for picking, and were able to pick off both sides; and it did not seem to him in looking back that there were a great number of men there. Of course, part of these were employed on the nut tables, and part on the dross tables. They were not all employed picking the round coal.

Mr DRINNAN said, in the same connection, it was stated on p. 173 that as the coal becomes less round the number is gradually increased to 4·6, or eight men and boys per waggon. That seemed to him a most extraordinary number at one waggon, and he would like to know what they were picking.

Mr GILCHRIST said he could not answer right away as to the number of men. Mr Cowan got these figures looked over, and as regards any little thing that they were in doubt about wrote afterwards and got information. Of course, they could understand that it took a larger number with small coal than lump coal. The biggest lumps were taken off nearest the scree, and what remained gradually decreased in size. What went over the ends would be about the size of one's two fists.

Mr DRINNAN said that his experience in connection with that was that there was a less number required where they were throwing the small pieces somewhat indiscriminately into the waggons. Where the coal was carefully picked there was one man lifting it off the picking table, and another inside the waggon packing it there. Another question of some interest was

as regards a statement on p. 168, near the bottom. He happened to have three ponds about the same size, and as the cost of cleaning was very considerable, he would like to know how they arrived at the conclusion that they only held 40 tons of dirt.

Mr GILCHRIST said they would require to get Mr Cowan's explanation of that, as the particulars were supplied to him after the visit.

Mr DRINNAN, referring to a statement on p. 177, said the best way of disposing of the dirt was the most difficult question of all, and he would like to know more of the process described in the second last paragraph of that page.

Mr GILCHRIST said the troughs were broad and very flat, so that the water in running through deposited the heavier particles on the floor. There never was more than possibly an inch of dirt there, the water being turned into another trough while the men were cleaning. This seemed to take out a good deal of the dirt, and it certainly was easier to take it out there than when it went into the deeper troughs.

The PRESIDENT said he heard recently of an experiment being made by Lührig's machine at Messrs Merry & Cuninghame's North Motherwell Colliery. They got in some hundred tons of debris which had come through a Robinson machine, and intended to wash it over again and take a great quantity of coal out of it. He thought if they had the result of that experiment brought before them it would be most interesting.

Mr DIXON said in the recently-published Transactions of the Federated Institutes of Mining Engineers there was the description of a tumbler. The bottom was a tank full of water, and it was so balanced that when the full hutch came on it tilted upside down, and the water was so distributed that the tumbler righted itself in a very neat manner. It seemed a good idea.

Mr GILCHRIST said he had seen a very good tumbler so arranged that when the hutch was run on, the attendant drew a lever which set the tumbler in motion, and it made one complete revolution very quietly, and as soon as the hutch righted itself it ran away. The attendant stood at the side table, and it completed the revolution in not more than 10 seconds.

Mr J. B. ATKINSON said at a colliery in Northumberland,

where they were working gas coal with a fireclay holing, they had a Ramsay Washing Machine for washing the small, and in washing the coal they got a good deal of dirt out of it. Iron plates were introduced into the pit, which the miners had to lay along the face for the coal to fall on, and they found it resulted in a large decrease in the amount of rubbish and dirt sent out of the pit.

The PRESIDENT said that would correspond with the "sliping" of coals. In some of the thin seams it was common to use slipes along the face, and draw the coal to the roadhead with them.

The SECRETARY said he understood that the use of the slipe was for convenience where the roads were far apart, when the seam was thin and the brushing hard the roads were sometimes laid off so.

Mr ATKINSON said the intention here was to keep the coal clean.

Mr DIXON said a similar practice was followed in filling coals on the bank. When on soft ground plates were put down, and the men filled the coal from there instead of from the ground.

Mr DRINNAN intimated that he meant at a future meeting to call in question the statement, p. 227, as to the length of the picking table, and the cost for labour.

The discussion was then adjourned.

The following paper on "Pit Ponies; their Feeding and Management," was then read by Mr J. B. HAMILTON :—

PIT PONIES: THEIR FEEDING AND MANAGEMENT.

By Mr J. B. Hamilton, M.R.C.V.S.

I have great pleasure in responding to the invitation of your Secretary, Mr Barrowman, to read a paper in connection with the feeding and management of ponies and horses in pits. In doing so, I am perfectly well aware of my inability to prepare a paper which will contain anything very original on the subject, as a very eminent member of my own profession—Mr Charles Hunting of South Hetton—who has made this subject a life-long study, has already written several exhaustive treatises on it. I also observe a most carefully-written paper by Mr Longden, read before the Chesterfield and Derbyshire Mining Institute, dealing with this matter. After looking over the two papers, I felt that a great many of my remarks had been anticipated by these gentlemen, but, as I believe this subject has not been before this Institute, it occurred to me that although I might be unable to add much that is absolutely new to recorded facts, still, the introduction of this subject to your notice may lead to a discussion which will prove profitable to us all. That this matter has not been formally discussed by the members of the Mining Institute of Scotland is not, I am certain, because the great importance of getting your horse motive power into good order, and keeping it so, is insufficiently recognised, but rather owing to the crowding of other subjects which have engaged your attention.

Independently of financial reasons, I would still feel confident in addressing you on humanitarian grounds, as I am very happy to record here the almost invariable promptitude with which any suggestions I have had occasion to make on my professional visits, towards the increase of the comfort and well-being of the ponies, have been acted upon by the proprietors and managers of collieries. Indeed, I am somewhat of opinion that in many respects the surroundings of a "pitter's" life are more pleasant than those of his brother on the surface. For one thing, he is not exposed to changes of temperature, to the hurricanes of wind and rain, and violent hail and snowstorms of our winter, or the sweltering heat and glare of a July sun. His hours of labour are usually shorter, and when he is lucky enough to meet with a kind

driver, anyone seeing his sleek coat and round plump body would form the opinion that he must be fairly happy, from a pony's point of view. The impression formerly prevalent amongst the public, that putting a pony to work in a pit is nothing short of condemning him to penal servitude for life, is now true in only a few instances. I understand that in former times less attention was paid to the comfort of the ponies by managers, but, at the present time, what with the wonderful improvements in ventilation and mining, and more intelligent methods of feeding and shoeing horses, I am convinced that in this district I could show many studs, which, in point of condition, cleanliness, and general comfort, are not one whit behind, but rather in advance of, many of the supposed more favoured of their species on the surface. And, I am sure, it will be agreed that it pays, apart from mere sentiment to feed well and treat kindly the dumb animals who so faithfully perform their duties underground, and occasionally under rather difficult circumstances.

Within a radius of six miles of Hamilton, there are, according to a rough calculation, about 2,000 ponies and horses used underground, the value of which will amount to about £20,000, and require an annual expenditure of £50,000 for their upkeep, &c.

These animals are drawn from nearly all parts of Northern Europe, and each presents a general distinct type of form and character. The Highlands of Scotland in time past furnished the greater part of the animals required; but at present those available and suitable from these districts are very few, and, consequently, dear. This scarcity is owing partly to the draining of former years, but mostly to the greatly diminished area under cultivation by crofters and small farmers, who were the principal breeders and workers of the "Highland sheltie." Inbreeding has also deteriorated the size, stamina, and power of endurance of this species. I should say there is not one good Highland pitter now for ten there were a dozen years ago, and this is the opinion of those dealing in the trade.

The Shetlander is a most diminutive creature, varying in height from 9 hands (36 inches) to 12 hands (48 inches). I do not know that they have ever been largely used for draining coal in the Hamilton district. The supply is now very scant, and the

demand from America being very great, the price is almost prohibitory for pits. A fairly good four-year-old Shetland horse pony, say 10 hands, is worth £16 at the present time.

The Icelanders are a most useful class of ponies, and I think I am safe in saying they pull nearly 50 per cent. of all coal drawn in the smaller seams around Hamilton. Their heights vary from 11 to 12½ hands. They make good pitters, as their temper, being rather sluggish but withal honest, adapts them for the frequent lifts they have to take slowly and steadily when starting their loads. The supply of ponies of this breed is also gradually diminishing, owing to emigration of the people from this most inhospitable region, and also owing to the large and ever-increasing quantity of ponies which are becoming absorbed into pits here and in the North of England.

The Scottish Highlands, Shetland, and Iceland were the principal sources from which the supplies of ponies were got, but, owing to the causes enumerated, the supply has greatly diminished, and consequently other countries had to be tried.

Russian and Hungarian ponies have been imported at Hull and London in large quantities for some years, and many of them have been purchased for pit work. They are not, however, in my opinion, adapted for this class of work, being generally very deficient in the loins, where the greatest strain in pulling hutches comes. Their height is from 13 to 14½ hands.

Norway and Sweden within the last year or two have supplied a considerable number of ponies to this country, mainly through the enterprise of Leith firms. The ponies of this breed are generally possessed of a most remarkably pliant and docile temper, and when carefully selected have proved splendid pitters. They vary in height from 12½ to 14½ hands—average, 13½. There seem to be two pretty distinct breeds of them—those which are mostly found in the lowland districts, and make good trappers; and the other, which are obtained from the more hilly districts, and are generally smaller in size, and with very small ears, and have wonderful development of the muscles in the loins and thighs.

A few of the most salient points in the formation of a good pit pony or horse may be here noted. In the first place, the general

character and temper can be seen in the face of a pony as well as in a man. Select one with a good broad forehead and a mild eye, if a little sluggish, a good deep chest to allow of plenty of room for lung play, a longish body, and barrel well ribbed home, broad muscular loins, and well-developed thighs. That the latter conditions are the most important in the structure of a pit pony is easily understood, when we consider that the act of pulling is like bending the body in the shape of a bow, and the long muscles of the loins, the gluteal muscles of the haunches, and the semi-membranoses and tendonoses of the thighs have to straighten the curvature caused by the weight of the load.

There are many other points, of course, which it is necessary to have in pit as in other animals, but I have merely touched on those, without which, I consider it is impossible to have the foundation of good pitters.

They ought of course all to be sound in a practical sense. No pony should be put into a pit under three years, and aged animals (over 10 or 12) which have been used for running with a light trap do not, in my opinion or experience, make satisfactory workers, as the duties are so different from those to which they have been accustomed. I have heard many opinions as to sex. Some say mares become troublesome. Others have experience totally opposite to that. My own opinion is that mares are not affected by the climatic conditions in pits, as the temperature being equable, the animal economy quickly accommodates itself to it. I wonder some coalmaster does not go in totally for mares, as they can usually be bought cheaper than the males, and are on the whole better workers and wearers.

Having then selected the animal, we have to consider how he may be best prepared for the work he is to perform.

Seventy per cent. of ponies bought for pits come straight from their native districts, and in most cases have never acquired a taste for grain of any sort. These are the animals which generally come to learn their duties best, as they are invariably sound, and have not been taught any tricks, and they also more readily acquire that gradual increase of pressure when starting the hutches which ponies that have been driven much in light vehicles seldom learn.

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The best method of teaching them to eat grain is to mix a little with plenty of cut hay, and gradually increase the quantity as they partake of it. This should always be done on the surface, but as soon as they commence to the feeding they should be taken underground. I have seen many animals spoiled through being kept standing on the hill, and fed up on a diet for which their digestive apparatus was quite unprepared. Of course, there are exceptional circumstances, which would modify this very much, as in connection with some collieries there are farms where the pony can be worked and exercised, but as a rule unless this can be done regularly they are much better below. It is here that the "tug of war" begins, for as soon as ever an animal reaches the bottom it seems to be expected to commence full work right away, and to do that work with all the sagacity of a veteran. Conduct such as this is very mistaken zeal, and becomes expensive to the owner. Besides the dangers attendant on its inexperience, there are those which arise from overheating, and various internal disorders, the result of exhaustion. What I would suggest is that the pony should be taken quietly to the stall or box, and allowed to remain in it for a day at least to accustom it to the darkness, &c. Then, if necessary, have it clipped, allowing the hair to remain on the legs to protect them from water and injuries. After remaining in the stable until it has become somewhat accustomed to its surroundings, and is feeding all right, the pony should get work for an hour or two daily, beginning with an empty hutch, and gradually extending its time and increasing the weight until it can do a whole day's work. Care should be observed by the ostler or man in charge to stop work whenever it refuses to feed. If these precautions were more generally adopted it would be found a considerable saving in every way, as 50 per cent. of all accidents and injuries occur when the animal is new to the work and its muscles and tendons are soft and flaccid for want of practice. The getting of an animal into hard, seasoned order is simply a matter of giving it work suited to it, and then supplying it with a sufficiency of healthy food in a digestible form, and containing the elements necessary to repair the wasted tissue.

The constituents of the bodies of animals are divisible into two

groups; the inorganic, or incombustible, represented by the saline materials or ash; and the organic, or combustible, which are again sub-divided into nitrogenous substances, represented by albumenoids and non-nitrogenous bodies, such as fats and starches.

The essential elements of animals and vegetables are alike, but they differ very much in the proportions relatively. Thus, the comparative amount of fatty matter present in vegetables, and principally represented by carbo-hydrates, such as sugar, starch, and gum, is much greater in proportion to nitrogenous matters than is found in the animal body. The use of this will be understood when it is remembered that besides supplying materials for building up the animal frame, and replacing tissue waste, food also provides combustible matters for the generation and maintenance of heat, and for the production of mechanical forces. Of these constituents, the vegetable nitrogenous matters, such as gluten legumen, etc., are similar in composition to, and usually go to form the animal nitrogenous matters as albumen, fibrin, caseine. They also furnish materials for the gelatinoids. By their combustion, heat and force are developed, but if only partial oxidation takes place, fat may be produced. Albumenoids, therefore, can supply most of the animal requirements, a statement which cannot be made of any other food constituent.

Fatty matter, whether true fats or carbo-hydrates, is the chief source of heat and force, but when given in excess is stored up in the shape of fat in the animal body.

In consequence of the limited amount of saline matter necessary for fully-developed animals, and which is amply provided for in the foods, it is unnecessary to consider them.

These food constituents before being available for assimilation, have to nndergo a process of digestion. This begins in the mouth, where the food is triturated and masticated. Some of the carbo-hydrates, such as sugar, etc., are soluble, and require no digestion, others again, such as starch and cellulose being insoluble, are here mixed with the saliva, whose special action is the conversion of insoluble starch into soluble sugar. Any starch unconverted in the mouth, passes through the stomach without change, its further digestion being completed in the

small intestines, where the complete conversion of starch and cellulose is effected by the action of the pancreatic and intestinal secretions.

Fats are not digested until they reach the small intestines, where they are emulsified and saporified through the agency of the bile and pancreatic juice. The digestion of albumenoids is mainly effected in the stomach, where they are acted on by the gastric juice, whose duty is to convert the indiffusible proteids or albumenoids into diffusible peptones. The constituents of foods being thus digested, undergo absorption in various parts of the alimentary canal, but chiefly in the small intestines, whence the digested materials pass either directly into the blood, or enter it through the intermediate lacteals and lymphatics. In the blood they are carried to the various tissues, where they either serve for purposes of nourishment, or by their combustion with the inhaled oxygen, from the atmosphere, produce heat and force. The products of combustion and tissue waste are ultimately carried off through one or other of the excretory channels. The function of food is to provide for this tissue waste and combustion; but however completely digestion of the food takes place, a certain portion remains undigested, and is ejected as fæces.

The following table, compiled from an average of many, shows the approximate composition of the various stuffs used for horse provender:—

Food.	Water.	Albumenoids.	Fats.	Soluble Carbo-Hydrates.	Fibre.	Salts.
Beans, - -	14·5	25·5	1·8	45·8	9·3	3·1
Peas, - -	14·3	22·4	2·0	50·7	7·9	2·5
Oats, - -	13·9	12·3	5·6	53·8	10·8	3·6
Barley, - -	14·0	10·0	2·2	64·2	7·0	2·6
Maize, - -	12·0	10·0	5·3	68·0	3·0	1·7
Bran, - -	13·5	14·0	4·0	49·1	14·2	5·4
Linseed, - -	12·0	21·5	38·0	17·0	7·5	4·0
Clover Hay, -	16·5	13·0	2·8	35·4	26·5	5·8
Grass, - -	76·5	3·1	0·8	13·0	5·6	2·0

It will be seen from this table that (1) the leguminous seeds contain twice as much albumenoids as the cereals; (2) that the special feature of the cereals is the large quantity of soluble carbo-

hydrates; (3) that maize is extremely deficient in ash constituents. However interesting and instructive these tables may be, they are very misleading if studied without some discrimination. Although practically accurate in the relative estimate they present of the feeding value of kindred substances, they cannot be relied upon in calculating the real feeding nature of such substances as oats and hay, for it will be easily understood that hay has not relatively such a high feeding value as oats. Bran would seem to contain as much nourishment as oats, but no practical person would expect the same amount of work from a pony fed on bran as one fed on oats. Let us endeavour to account for this apparent anomaly in the tables. It has been the custom to reckon the whole of the nitrogen present in a food as albumenoid. Whilst this is fairly accurate as regards the seeds, it is not so with the other foods, as a considerable quantity of the nitrogenous matter in bran, for instance, has been found to be indigestible, or digestible if non-albumenoid, and acting simply as a fat former. Again, in hay it will be found that only the half of the *organic* matter is digested, against 80 to 90 per cent. in corn. In calculating the nutritive value of foods, a very important item is the albumenoid or nutritive ratio, or, in other words, the proportion which exist between its flesh formers and fat formers. In calculating this, it is usual to multiply the fat present by 2·44, so as to obtain the equivalent in starch, and then add the product thus obtained to the carbo-hydrates. The relation of flesh formers to fat formers reckoned as carbo-hydrates is then easily obtained. Thus—

Beans show an albumenoid rate of				...	...	...	1 to 2·3.
Oats	,,	,,	,,	...	...	...	1 to 6·4.
Maize	,,	,,	,,	...	...	...	1 to 8·3.

It may also be shown that a mixture of 100 lbs. of beans and 400 lbs. of maize contains quite as many of both fat and flesh formers as 500 lbs. of oats, and at the same time the albumenoid ratio of the former is fully equal to that of the latter.

We are greatly indebted to German experiments for information as to the digestibility of the various foods. They have shown us the relative digestibility of foods by various animals, and also that the digestibility of a given food by the same animal may be sometimes considerably increased by the addition of an

article rich or poor in the particular constituent, deficient or abundant in the food in question. Thus the digestibility of potatoes, which are particularly rich in starch, will be increased by supplying along with them a nitrogenous article such as bean meal, &c., and *vice versa*. In this way a judiciously-mixed diet will usually give the most satisfactory results.

The digestion of the various food stuffs by the horse is shown by the following table, which also gives some of the results of the experiments before mentioned :—

	Proportion of Each Constituent Digested for 100 Supplied.				
FOOD.	Total Organic Matter.	Albumenoid.	Fat.	Soluble Hydrates.	Fibres, &c.
Pasture Grass, ...	62·1	68·8	13·4	65·8	57·0
Meadow Hay (good),...	51·7	64·3	23·5	56·9	42·6
" (inferior),	46·3	58·4	18·8	51·7	37·3
Oats, ...	72·0	87·0	78·2	76·6	25·6
Beans, ...	87·4	86·2	8·5	93·4	69·3
Maize, ...	90·9	77·6	63·0	93·9	100·0

In the total of digested organic matter, maize stands at the head of the list, while in digested carbo-hydrates it is equal to beans and superior to oats. It will be seen, however, that maize as a digested albumenoid is inferior to both oats and beans.

Beans and peas show an almost identical composition. The beans in the market are principally either English or Egyptian. The former are generally preferred, as they are usually somewhat sweeter; but in practice there seems little difference in their feeding value, and the Egyptian are rather cheaper. They should be old, dry, and clean, and be between 60lb. and 66lb. per bushel in weight. Peas are frequently substituted for beans, being only slightly inferior in feeding value. Canadian peas should be clean, hard, and clear of worms. Beans and peas are far too nitrogenous to be given alone for any length of time, but they are very valuable for increasing the albumenoid ratio of food deficient in nitrogenous materials.

Oats have always been considered as the best food for horses, and, certainly, if one could only have one variety of grain, it is the best. This is proved by practice, and confirmed theoretically by comparative analysis, which shows oats to possess the chief food constituents in better balanced

proportions for the horse requirements than any other single grain. But although oats are superior, single-handed, to any other grain, they may be easily improved upon, and a mixture readily obtained containing the requisite constituents in a more justly proportioned ratio than in oats.

There are great differences in the amount of husk present in different varieties of oats, some containing 28 per cent., and others as much as 38 per cent. They should be uniform in size, hard, clean,and sweet in smell, and not under 40lbs. per bushel. All soft,new, bleached,kiln-dried, or musty oats should be rejected.

Barley is sometimes substituted for oats, but as the husk is very hard and indigestible, and causes much irritation to the intestinal tract and skin, I do not think it should be used unless in very small quantities. I remember being consulted by a farmer who lost several fine horses, and on making a *post-mortem* examination, I found the intestines completely packed with husks of barley. He had been feeding almost entirely on raw barley.

Maize is a grain which is being used for horse-feeding more and more each year. It is too deficient in albumenoids to alone maintain a horse in full work, but should always be given mixed with beans and peas. There has been, and still exists, a considerable prejudice amongst some horse owners as to the use of maize. I consider this has arisen, in a great measure, from its having been injudiciously used. When maize is crushed—and it should never be given otherwise—and a due proportion of a nitrogenous food, such as beans or peas and oats, mixed with it, it is perfectly safe, and may take the place of oats, very often at a considerable saving in cost. I have had an extensive experience of this mixture of foods while superintending a stud of tramway and omnibus horses in London, and can testify to the almost total disappearance of stomach and bowel affections by the use of this grain, whilst the horses kept themselves in a more healthy condition than if fed on oats alone. Practice in this case has amply vindicated theory.

Hay or fodder is an essential element in horse-feeding, as, however rich the food may be in albumenoids, fats, &c., if it does not possess the requisite bulk, a feeling of hunger remains. I remember seeing a stud of horses, which were experimented upon

with a concentrated form of horse biscuit, containing all the constituents necessary for health and work (chemically), and after having tried it for a week, and they had eaten all the woodwork within their reach, it was found necessary to return to the old bulky diet. It is only when the stomach is filled that the cravings of hunger are allayed.

Hay varies very much according to the nature of the soil on which it is grown. It also varies in a most surprising manner according to what stage of maturity it is in when cut. The general conclusions arrived at are that, as the plant matures, the proportions of water, nitrogenous matter, fat, and ash decrease, whilst carbo-hydrates increase. Now, as albumenoids are much more valuable than carbo-hydrates—and the greater the percentage of albumenoids in a given sample of hay, the easier will it be digested—it follows that, as the plant grows older, its nutritive value diminishes, as also its digestibility. This partly explains why animals should fatten so much more readily when fed on grass alone than on hay alone. Good hay should be cut before the bloom leaves it, and be bright greenish in colour, with a pleasant odour.

It is of great advantage to give a supply of green meat during the season.

The safest and most economical method is to cut it up and mix it with the chop. Of course, it will have to be used very soon, as it quickly heats. The use of green food is not only an agreeable and beneficial change, but is also an economical one.

Straw is sometimes mixed with cut hay. For this purpose, good oat straw is superior to wheat.

Bran is sometimes used amongst horse food, but its value as a food bears no relation to its cost. From its appetizing, corrective, and laxative properties, it is given with benefit to those off work from any cause.

A sufficient supply of pure water should always be at hand, and, when the relatively small size of the horse's stomach is considered, the necessity of giving water before feeding will be seen. If no water be given until after feeding, it is physically impossible for both food and water to be retained in the stomach —consequently a quantity of the food is washed into the intestines

undigested, where, in addition to its being a loss, it may ferment, and, by the evolution of gas, set up flatulent colic and other kindred disorders.

In horse feeding, both the animal and its work have to be considered, and due allowance made for the kind, quantity, and quality of its food. It is obvious, therefore, that no fixed diet can be made either in the quantity used or its albumenised ratio. The food must be directly proportionate to the work, as one pony will do more work than another, and so the quantity sufficient for one will be insufficient for the other; but an average may be taken over a quantity when they are similarly employed.

In regulating the food allowance, a careful and intelligent man will quickly see any necessity for an increase or the reverse. Economic feeding, or, in other words, the giving of such provender as will maintain the horse in the best condition, and obtain the greatest amount of work at the least possible cost may be achieved by the use of a food consisting of a mixture of oats, beans, peas, maize, and hay, the mixture varying in its proportion from time to time as the prices of the articles composing it fluctuate in the market, provided always a due albumenoid ratio be maintained.

The following mixture may be considered a fair blend:—

	No. 1.	No. 2.	No. 3.
Beans or Peas,	2lbs. daily.	2lbs. daily.	0lb. daily.
Maize (bruised),	6 ,,	4 ,,	4 ,,
Oats,	4 ,,	3 ,,	3 ,,
Bran,	0 ,,	2 ,,	2 ,,
Hay (cut),	12 ,,	12 ,,	12 ,,
Straw,	2 ,,	2 ,,	2 ,,
	26	25	23

Mixture No. 1 is an average day's feed for a pony of 15 hands, fully matured and seasoned, and doing a fair day's work. When the animal is new to the work and lean, and the muscular system, which absorbs the greater portion of the albumenoids, requires building up, I would use feeding No. 2. When a horse is off work for any length of time through lameness or other causes, use No. 3 feed. The latter feed, in equal proportions to bran, makes a very useful horse's feed when the animal is sick.

I think maize and oats should always be bruised, as they possess a very large proportion of digestive carbo-hydrates, and consequently require to be thoroughly masticated and mixed with saliva.

There is a considerable difference of opinion existing amongst experts as to whether any food should be given cooked or not. I have known many instances where ponies have done very satisfactorily for many years on this mixed diet without getting any boiled food. It is urged by the advocates of raw feeding that when food is cooked, animals do not require to masticate it, and consequently the food is not so intimately mixed with the saliva in the mouth. As I indicated before, the saliva performs a very important function in the process of digestion by assisting in the conversion of insoluble starch into soluble sugar; and if the food is simply bolted, it is impossible for this to take place without indigestion and colic resulting. This statement is quite true about the old compositions of boiling, which generally consisted of a rich gelatinous mass of beans, barley, a few roots, and a little chaff mixed. I am not surprised at horses taking colic after a feed of this on an empty stomach—indeed, it is a wonder so few succumb to it.

If, however, a feed of the mixture I have referred to be steamed or boiled, and a little bran added, it will be found of great advantage when the animal comes in tired and exhausted after a severe day's work. The cooking renders more of the food digestible and easier digested, and the large bulk of cut hay and straw necessitates a thorough mastication. I think that where the animal is in good condition, and the work not too oppressive, it is better to be put entirely on the raw feeding; but when it becomes worn down and low in condition, cooked food of the nature I have advocated will be found extremely beneficial.

As the stomach of a horse is very small, relatively to the animal's size, it should be fed at least four times daily, and always given water before being fed. In many collieries it is supposed to be impossible for the pony to get sufficient time between his journeys to eat such a bulky form of food as I have advocated. I think, however, that this difficulty could be got over by having a sufficiently large box at the part where he stops, so that he

might be enabled to expend all his spare time in eating. By leaving out a portion of the cut hay this difficulty can be obviated. At a considerable number of the collieries in Hamilton district this mixture has already been adopted, but it seems to have been forgotten in the making of the mangers that this food is more bulky than if composed of oats alone. The result is that a very considerable quantity of the food is lost through being tossed on the ground. A manger should be at least 3ft. long by 2 broad and deep. Two iron bars should be put across, 6 inches from each end, to prevent the pony throwing out the food. There are no better mangers than those made of galvanised iron, bevelled at each end, of about the size I have mentioned, and which can be taken out and cleaned when necessary from a wooden form fitted to receive them. I have seen 2500 of them in use in one establishment with most satisfactory results. All mangers of whatever composition should be water-tight, as all the food given should be damped in the manger. The damping facilitates the mixing of the saliva with the food while being masticated, and, besides, the animals seem to eat it better than if dry and harsh. A table-spoenful of common salt daily sprinkled in the manger on food is very beneficial.

Horses should be allowed about 800 cubic feet of space in the stable. "The lungs of a horse will contain nearly 1½ cubic feet of air, and at each inspiration 130 cubic inches are drawn through the trachea, and the surface of the lungs to which this air is exposed is calculated to be equal to 289 square feet." Air then containing impurities, particularly gaseous, is exposed to an absorbent within the body equal to 5½ times the surface of the skin.

From this extract you will see the necessity of having a plentiful supply of *pure* air. There is probably no cause, or aggregate of causes, which has contributed so much to the production of disease as foul air. All that has been said may be formulated in the precise language of Parkes—"Disease and health are in the direct proportion of foul and pure air." With regard to bedding, I think moss litter is the best, as it is the best absorbent, and not only does it absorb much more than either sawdust or straw, but it seems to have some power of fixing the ammonia which is

generated by the decomposing excreta. Where moss litter is not available, some sawdust should always be used in addition to straw, so as to absorb the liquid excreta. This is the best form of drainage in stables.

A great deal might be written on shoeing of ponies in pits, and I think much more attention should be given to this matter than is done at present. In this district it is customary to shoe with toe-pieces and calkins both fore and hind. Now, I don't object to a low toe-piece and calks on the hind shoes, keeping the feet fairly short at same time, but the system of setting the fore feet up on a set of stilts is absurd. The frog of a horse is composed of a material resembling india-rubber, apparently for the express purpose of breaking concussion, and giving the horse gripping power on a hard surface. A knowledge of this fact will at once indicate the style of shoeing to be adopted on fore feet. The frog should be allowed to grow to its full size and never be pared, and a plain flat shoe used with plenty of iron in the web. Nearly all the horses in London are shod in this fashion, and the loads are heavy enough and roads sufficiently slippery to test this form of shoe thoroughly, and yet they rarely pull themselves down.

With respect to feeding, grooming, harnessing, and stabling, I will merely say that in proportion as they are attended to so will the physical fitness of the pony be insured. They comprehend so many details that it is impossible to deal with them in a single essay. If the ponies be good, and plenty of food, both in quantity and quality, is supplied, then their welfare depends on those who attend to them. Only one thing more I would like to refer to, and that is the necessity of inculcating kindness on all who have to do with horses. Physical fitness is closely allied to mental fitness, for that horses have minds, affections, and memories, no one can deny, and all who have studied them will bear testimony to the effect of ill-treatment and kindness upon them, not only in the performance of their work, but in their durability.

DISCUSSION.

The PRESIDENT characterised the paper as a most interesting one.

Mr JOHN DRINNAN, in reference to the supply of water to ponies, drew attention to the great preference which they had for dirty instead of clean water, and asked what Mr Hamilton had to say to it.

Mr HAMILTON said it was sometimes a symptom of a deranged stomach when they drank dirty water. They saw the same thing in cattle. In pits, the reason they might prefer to drink dirty water was owing to the presence of some saline matter in the liquid.

The discussion was adjourned.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE

ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,

13th March, 1890.

JOHN M. RONALDSON, Esq., President, in the Chair.

The minutes of the last General Meeting were read by the Secretary, and confirmed.

The following were elected by ballot as ordinary members:—

THOMAS ROBERTSON, New Lodge, Slamannan.
WILLIAM DRAPER, Seaham Colliery, Sunderland.
JAMES GRAY, Cumnock.
WILLIAM A. KIRKWOOD, Clydeview, Larkhall.
JAMES NAPIER, 16 Whitevale Street, Glasgow.
NIGEL MACFARLANE, Blantyre Collieries, Blantyre.
ALLAN D. BELL, 123 St. Vincent Street, Glasgow.
THOMAS B. CAMPBELL, 123 St. Vincent Street, Glasgow.
JAMES BAIRD, Carnbroe Iron Works, Coatbridge.

The SECRETARY, on behalf of the Council, submitted the names of the Members of Council who were eligible for re-election as office-bearers for session 1890-91.

The nomination of office-bearers for session 1890-91, in terms of Sec. 5, Art. 3, of the Rules, then took place.

The following discussions then took place:—

DISCUSSION OF THE REPORT OF THE COMMITTEE ON COAL-CLEANING.

The SECRETARY said, with reference to the statement on p. 250, he had the following note from Mr Henry Aitken :—"I see it stated that Mr Whitelaw made the first revolver or table for picking coal. I do not know when Mr Whitelaw made his, but some nineteen years ago I had working at Boghead Colliery a revolving table, which also riddled the coals and put them into the truck—the coal being put on the table or riddle from the hutch, which was emptied by a side couper provided with a hinged lid to let out the coal when it had turned right round."

Mr A. M. GRANT said there was an explanation asked at last meeting (at which he was not present) by Mr Drinnan with reference to a statement on pp. 137-148 of the report, and the explanation was as follows :—The water from the coal washers *E E'*, after passing through screen *G* at hopper, formed its way by means of shoots to the small coal basin *J*. The shale or dirt from both nut and felspar washing machines is delivered into the basin *P*, and the water from this basin overflows into the basin *W*, and the water from here overflows again into the basin *J*, on its way to the large tank *T*, from which the centrifugal pumps draw it for re-distribution among the machines. The word "dirt" in the text should have been "small coal," because the water in the tank *W* is almost quite filtered before overflowing into the basin *J*, and is simply discharged into it to find its way through the small coal into the tank *W*, to be pumped over again for coal washing. The water from tank *W* could easily be sent on to the tank *T* by a separate shoot or drain, but I presume in this case it was found most convenient to send it on by basin *J*.

Mr JOHN DRINNAN said, on the second page of the "General Conclusions," the Committee laid down that there should be "one picking table for every 30 tons per hour of triping output, travelling at the rate of 40 feet per minute, and having an effective length of 10 feet for every 3 per cent. of material to be picked off, *plus* 15 feet." Now, it struck him at once that that was a very small quantity indeed to pass over one picking table when the speed was 40 feet per minute, because he thought 2

tons might easily be spread over that 40 feet, and not be by any means thick. That was 4 feet wide and 20 feet in length per ton, and, if they had a ton spread over that, any particular class of coal could easily be picked out of it. And if there were two tons spread over that 40 feet, and two tons were passing over it every minute, they would have a very much larger output than what was stated. That was assuming that the picking-table had facilities for enabling them to pick from both sides. One reason why he thought it was desirable that attention this should be called to was that, if people generally were allowed to believe that it was necessary to have one picking table to every 30 tons per hour of triping output, they might think it necessary to have a large number of tables for three times that. That would cause a great outlay for sidings and tables, and would be altogether unnecessary, for he had seen a much larger quantity passed over, and much more than 30 per cent. picked out of the coal. A picking table of about 60 to 70 ft. in length should go at less speed than 40 ft. per minute. He had seen it done, and, of course, concluded it would be a very easy thing to do it again. If the Committee had said from 90 to 100 tons, he thought that would have been much nearer the mark. He thought it would be very possible to pass that over one picking table.

The PRESIDENT—One picking table would deal with a pretty large output.

Mr DRINNAN—Yes.

The SECRETARY said perhaps it was as well he should refer generally to Mr Drinnan's criticisms; and, in doing so, he might mention generally how the conclusions took shape. Each member of the Committee was invited to state his general conclusions. They were all sent to him, and he put them in shape, and sent the conjoined conclusions to each member for his criticism, and after that there was a meeting. Well, of course, certain paragraphs were the product of certain individuals, and the gentleman who suggested that paragraph had since told him that he had revised the figures in the report, and that the result justified the conclusions as recommended. It is possible there might be tables which did more or less work, but the facts stated in the report justified that conclusion.

Mr DRINNAN said if these be the facts, he was inclined to say so much the worse for the facts, for he was still of opinion that a much larger quantity could be passed over than that. He pointed out, if the residue of the coal after leaving the picking table had to be lifted by elevators to the screens, then the buckets must be large enough for the purpose, and with sufficient screening accommodation, he thought there was nothing at all to hinder the picking table described to pass it at the speed referred to.

The PRESIDENT—Have you made allowance for the intervals when no coal is being picked?

Mr DRINNAN—I was stipulating for that.

Mr COWAN asked Mr Drinnan if he meant that he had taken 30 per cent. of dirt out of the coal.

Mr DRINNAN replied in the negative. He meant that 30 per cent. of the coal was being picked out.

Mr JAMES GILCHRIST said a number of the tables were passing 600 to 800 tons over a single table. At one colliery there were about 600 tons passing over one screen. Of course, it was divided into three tables. First of all, in one division, the nuts were passed on to the second table, and the smaller coal was passed on to the third table for picking. At other two collieries, there were from 600 to 900 passing over single tables. Of course, the length was very great, about 250 feet. In that case, the dross was not taken from the coal. The triping was passing along the table, and screened in at the ends, and he did not see anything to keep them from passing between 500 and 600 tons. They had done that at Earnock, having passed between 500 and 600 tons over one table, but then everything was kept going at its very best. It was possible to do that over one table. Of course, the dross was passed away to the lifter, and being treated separately it passed into waggons.

Mr GRANT said the 500 or 600 tons was passed over in ten hours.

Mr GILCHRIST—Nine and a half hours.

Mr GRANT—It is 300 in ten hours, but it was a rough and ready rule, and he should imagine the minimum quantity was stated there. In South Wales they had, unfortunately, not had

an opportunity of seeing any picking tables, because the coal required no cleaning so far as they saw. He thought the figures were as Mr Drinnan had stated, but in the report it was the minimum quantity, and if they forced it up they could get 600 tons.

Mr COWAN said the only thing he would like to impress on the members, in dealing with the Report and the question of coal-cleaning generally, was what was stated in the first paragraph of the "General Conclusions." Now, if that was borne in mind, he thought there would be a great deal less waste of time in talking of petty details. Any one going in for fitting up a coal-cleaning plant should consider the examples in the book as only suggestions, and not copy them absolutely, but study the thing for himself, and having found out what he wanted should see that he got it.

The PRESIDENT, in closing the discussion, said he thought they would all agree that none of them would regret having sent out the Committee to make the investigation, and to bring before them the results. They had obtained a most valuable contribution to the Transactions, to the benefit not only of the members of the Institute, but all connected with mining. He thought the least they could do was to accord them a most hearty vote of thanks for the time and the trouble they had taken in preparing their report. (Applause.)

DISCUSSION OF MR J. B. HAMILTON'S PAPER ON "PIT PONIES; THEIR FEEDING AND MANAGEMENT."

The SECRETARY mentioned that in the second last line, p. 261, the word printed "draining" should be "drawing."

The PRESIDENT remarked on the great attention that was now paid to the judicious mixing of food, and said, of course, it was science that had brought this prominently before them. Doctors told them what were the best proportions of food for human beings, and the same applied to horses, and he thought there was a great deal yet to be done in regard to the judicious mixing of the different foods for horses. They all knew that at collieries there were steam engines which were nothing but coal-eaters. They used a great deal of coal, and they produced only small results. He was afraid in many cases still their horses were not fed properly, simply through ignorance of what were the proper constituents to give them. Their food was probably more expensive than some of those mixtures which Mr Hamilton describes in his paper, while the results were not so satisfactory.

Mr MARTIN, referring to the recommendation as to salt at p. 273, asked the quantity that should be given.

Mr HAMILTON—One spoonful to each animal daily.

Mr MARTIN said some ostlers kept a piece of rock salt in the manger.

Mr HAMILTON said that served much the same purpose. Still, as a general rule, the mangers were very small, and the bulk of the food and the dampness would, with the rock salt, be apt to make it too salt.

The PRESIDENT said, with regard to the treatment of pit ponies, he was glad to say, so far as he could see going about the district, there was not much ill-treatment prevailing. There were a few cases, he was sorry to say, but they were really very few. The last Mines Act had put it on Inspectors to look after the treatment of pit ponies, and he thought there was no one who would say that it was a thing they should not enquire into, because only those who went into the mines saw them, and they ought to be treated kindly. Moreover, in all cases they would find it best to treat those faithful servants with kindness.

Mr HAMILTON said he was in the expectation that he would

have had some criticism on his paper. He knew that in private he had heard a good many different opinions given by different managers, and as there were still some advocates of the old system of feeding by entire oats, he should like very much if some of the gentlemen still continuing that practice had spoken on the subject and given him an opportunity of contrasting the two in regard to price. They would observe, in the paper, he had not touched on it. He had put before them what he considered the best system of feeding, and did not touch on financial matters at all. Proceeding to contrast the cost of the two feedings, he said they would observe in the analyses of the different foods on p. 267, after showing the elements of flesh formers to fat formers, he had stated 100lbs. of beans, 400lbs. of maize, and 500lbs. of oats, but at the same time it would be noticed that there was a considerable portion of the oats which went for husk, and was indigestible—altogether nearly a third, so if they took say 2lbs. of beans and 8lbs. of maize, making a total of 10lbs. it would be equal in results for feeding value to 15lbs. of oats. Putting them at the current prices given to him by a grain merchant that day, viz., 11s for 280lbs. beans, 16s for 250lbs. oats, and 16s per 240lbs. maize, the results financially were that 10lbs. of the mixed grain came to 3s 7d or 3s 10d per week, while the 15lbs. of oats come to 6s 4d, or nearly double. He had heard the opinion that animals fed on mixed food would not be able to do so much work, but experience showed that on the two foods the results were nearly the same work, so that practically they found the mixture was fully vindicated in showing that fact.

The SECRETARY said that in conversation with a coalmaster, who had a large number of horses, he asked him as to feeding with boiled food, and he said he had given it up with the underground ponies, but he still used it for the horses on the surface, as he thought horses employed in exhausting labour on the surface were the better of boiled food. A friend of his own whose horses had used that for many years had said he would like to be satisfied that the other was better before giving it up. Perhaps Mr Hamilton would say whether he considered there was any essential difference between horses carting on the surface and underground ponies justifying soft food for the former.

CALIFORNIA STATE

Mr HAMILTON said he had referred to the matter of boiled food at p. 270. That was a point on which there was a good deal of difference of opinion, even among many members of his profession. Many advocated entirely dry food. Whilst in London he had charge of 2500 horses, and they used nothing else but oats. They, however, found that if there was any case of illness, and the animals became lower in condition, it was necessary to cook some of their food. He thought it was the condition under which the cooked food was given that the great point of danger lay. The old system was to boil beans and add a little bran. That was a very rich, gelatinous food, which required little or no chewing. Now, it was necessary that it should be chewed and mixed with saliva, which had an important function to perform. So, if they fed animals in that way when they came in, as they usually did at night, tired and hungry and the stomach empty, without taking into consideration the smallness of the stomach, and that, after a long want, they simply bolted this food and did not chew it, of course this would give rise not only to loss of the food, but many times to illness and colic, from the food passing through the stomach undigested into the bowels. That was where the trouble lay. Instead of giving rich food with a little bran, give it along with plenty of cut hay, so that the animal would require to eat it and take a certain time to swallow it. He thought such boiled food was judicious, and he had advised its use in many cases. Of course, where an animal was quite up to its work and healthy he thought dry food did very well.

The PRESIDENT closed the discussion, and expressed the indebtedness of the Institute to Mr Hamilton for his valuable contribution. It was a subject that they had never had before them in the past, and he had no doubt, now that it had been brought so prominently before them, greater attention would be given to the feeding and management of pit ponies in the future than in the past. He proposed a vote of thanks to Mr Hamilton, which was heartily given.

The following paper by Mr John Todd, on "An Improved Carriage for Self-Acting Inclines," was then submitted:—

AN IMPROVED CARRIAGE FOR SELF-ACTING INCLINES.

By JOHN TODD.

FIGURES 1, 2, and 3 show a carriage constructed for the purpose of working large hutches upon steep seams. This idea suggested itself when laying out the workings in a 4-ft. seam, at an inclination of 1 in 5, from which it was intended to

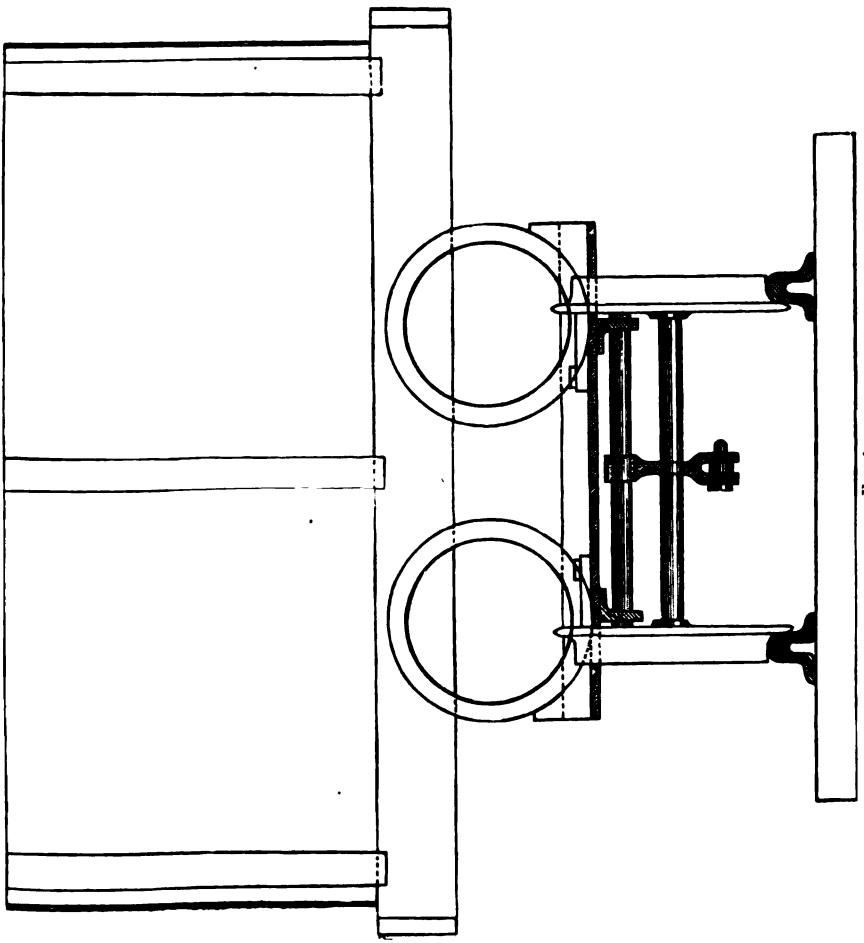
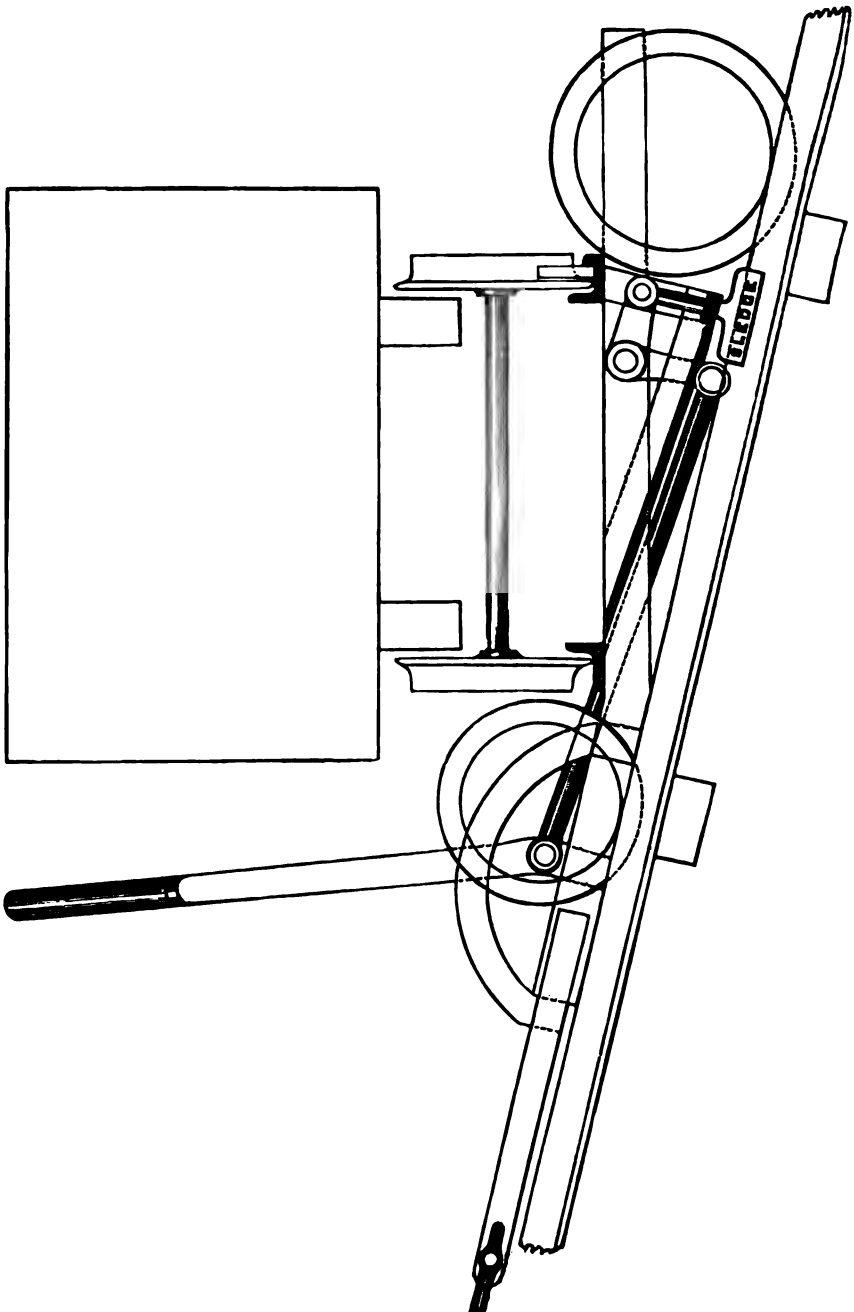


FIG. 1.


SLEEPER

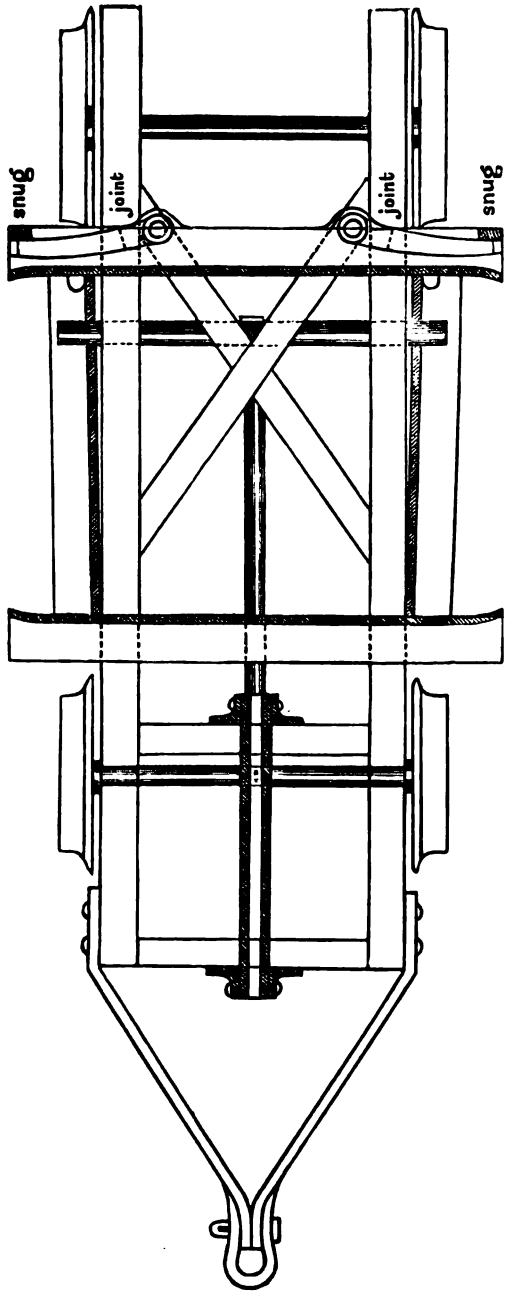


FIG. 3.

draw a large output, and in order to do this it was necessary to introduce large hutches. The difficulties which presented themselves were the turning of heavy hutches upon plates, and the apparent danger involved in working with cut chains, a system largely adopted in East Scotland.

The leading ideas are:—The carriage is constructed with a sledge-brake, which acts upon the rails. The gauge is the same as that for the hutches, which are used in driving the headings. The length that each carriage may work will be regulated by the output coming out from each place. The person in charge takes off the loaded hutches, and puts on the empty ones, and he travels with the carriage like a guard on a railway train. The arrangement is worked with a back balance connected to the carriage by either a wire rope or a chain round a pulley at the top of the incline, and goes up and down the headings like a single cage in a pit.

As shown on fig. 4, the back balance is fitted with a "jock" attached to the bottom, which has a lock joint that only allows it to fall as far as operate, and then holds it rigid. A spring is fitted between the bottom of the back balance and the "jock," which is held in position by a chain attached to the main rope. By this means a pressure is kept upon the spring, and in the event of the rope breaking, the spring presses the "jock" into the ground and prevents any serious damage. The carriage is constructed of iron; the trams are of angle iron carried under the front axle and secured to it with steel pedestals. A hole is made in each tram through which the brake shaft passes, and projects from each side, where a crank is put on and the sledge spindles attached to the end of it. At the centre of the brake shaft there is another crank connected by a round bar of iron to the lever, and when the brake is applied the connecting rod is brought into tension and the sledge spindles into compression.

This principle of a brake has been found to work very successfully on cable tramways with steep gradients.

The hutches are held upon the carriage with a latch on each end of the rail, which is attached to it with a joint which admits of a lateral movement. The latch is fitted with a joint

that works vertically, and thereby enables it to rise over the snug which is placed upon the rail to hold the latch in position when in operation.

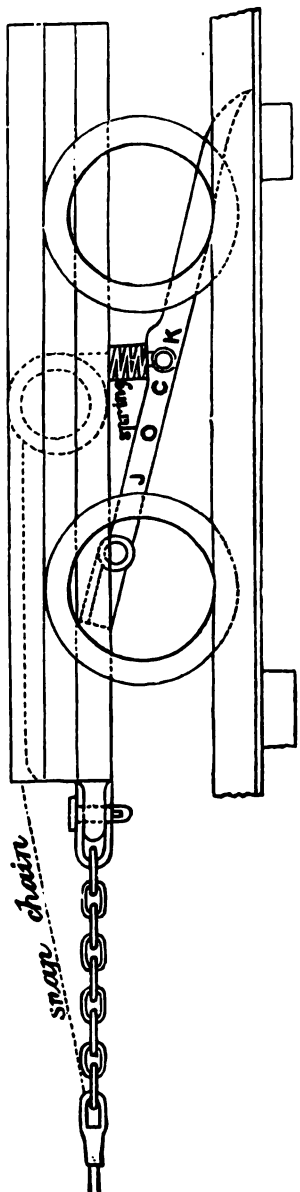


FIG 4.

The Mining Institute of Scotland.

1889-90.

HONORARY MEMBERS.

	Year of Entry.
MOORE, RALPH, H.M. Inspector of Mines (Retired), 13 Clairmont Gardens, Glasgow *(Past President)*, -	1878
ROBSON, JOSEPH T., H.M. Inspector of Mines, Swansea *(Past Vice-President)*, - - - -	1878
RONALDSON, JOHN M., H.M. Inspector of Mines, 44 Athole Gardens, Glasgow *(President)*, - -	1879
ATKINSON, J. B., H.M. Inspector of Mines, 10 Foremount Terrace, Glasgow *(Vice-President)*, - - -	1889

LIFE MEMBER.

Cadell, H. M., Grange, Bo'ness, - - - -	1888

ORDINARY MEMBERS.

Subscription £1 1s.

Adam, William, Blantyre Saw Mills, High Blantyre, -	1887
Adams, David, Hill of Beath, Crossgates, - -	1888
Adams, James, Hill of Beath, Crossgates, - -	1880
Adamson, James C., Victoria Place, Airdrie, - -	1887
Aitken, Henry, Darroch, Falkirk *(Past Vice-President)*, -	1878

Allan, Alexander B., 53 Waterloo Street, Glasgow, - 1887
Anderson, George, Ashton Villa, Plains, Airdrie, - - 1880
Anderson, James, Farme Colliery, Rutherglen, - - 1880
Angus, John, Muirkirk Iron Works, Muirkirk, - - 1884
Arnott, Thomas, Clyde Cottage, Tollcross *(Councillor)*, - 1879
Arrol, Arthur T., Germiston Iron Works, Petershill Glasgow, Road, - - - - - 1879
Atkinson, J. B., 10 Foremount Terrace, Glasgow, - 1889
Austine, John, Ellerslie, Hamilton, - - - 1878

Baird, Archibald, Park Road, Hamilton, - - - 1879
Baird, Matthew B., Charleville, Uddingston, - - 1880
Baird, Robert, 141 St. Vincent Street, Glasgow, - - 1879
Barr, William, Over Dalserf Colliery, Larkhall, - - 1879
Barrowman, James, Staneacre, Hamilton *(Secretary)*, - 1879
Bell, James, San Fermin Mining Company, Portugalete, Bilbao, - - - - - - 1881
Bishop, George A., Royal Bank, Coatbridge, - - 1879
Blackadder, Alexander, Stand Colliery, Airdrie, - - 1880
Borland, Thomas, Halbeath, Dunfermline, - - 1880
Bowie, W. T., Royal Exchange, Glasgow, - - 1890
Brand, A. Douglas, 6 Dixon Street, Glasgow, - - 1881
Brown, Thomas M., Lanemark Colliery, New Cumnock, 1880
Brown, Walton M., 3 Summerhill Terrace, Newcastle-on-Tyne, - - - - - - 1887
Brown, William, Largoward, St. Andrews, - . 1888
Bryson, D. R., 69 Buchanan Street, Glasgow, - - 1889
Buchanan, D. C. R. C., Drumpellier, Coatbridge, - - 1881
Cameron, Robert, Balbardie Colliery, Bathgate, - - 1879

Cameron, William J., Finnie Street, Kilmarnock, - 1885
Campbell, Archibald, Redding Collieries, Polmont Station, 1883
Carlow, Charles, The Fife Coal Company, Leven,- - 1879
Clark, James, Ormiston Station Colliery, Ormiston, - 1880
Clark, Robert, Arniston Colliery, Gorebridge, - - 1883
Colquhoun, James, Tredegar Iron Works, South Wales, - 1882
Cowan, David, Carron Iron Works, Falkirk *(Vice-President)*, - - - - - - 1879
Coats, William A., Ferguslie House, Paisley, - - 1884
Crampton, Jeremiah, The Point, Durban, Natal, - - 1887
Cross, James, 445 Eglinton Street, Glasgow, - - 1890
Cuninghame, Alex., Carnbroe Iron Works, Coatbridge, - 1880
Cuninghame, J. C., 127 St. Vincent Street, Glasgow, - 1879
Cuninghame, John, 127 St. Vincent Street, Glasgow, - 1879

Dalzell, John B., Portland Park, Hamilton, - - 1881
Denniston, R. B., 79 Princes Street, Dunedin, N.Z., - 1886
Dick, Alexander, Denby Colliery, Derby, - - - 1884
Dixon, James S., Bent Colliery, Hamilton *(Past President)*, 1879
Dunlop, Colin, jun., Quarter Collieries, Hamilton, - 1884
Dunn, David G., Coilsholm, Cambuslang,- - - 1882
Dunn, Hugh S., Earlston Villa, Caprington, Kilmarnock,- 1885
Durie, John, Elphingston Colliery, Tranent, - - 1880

Ferguson, Peter, 19 Royal Exchange Square, Glasgow, - 1885
Forgie, James T., Bothwell Collieries, Bothwell, - - 1878
Forrest, John Clark, Hamilton, - - - - 1885
Frame, Alexander, Larkhall, - - - - 1887
Frew, Robert, 75 Bath Street, Glasgow, - - - 1879

Galloway, Robert L., 43 Mair Street, Plantation, Glasgow, 1884
Galloway, T. Lindsay, Argyll Colliery, Campbeltown, - 1880
Gardiner, David, Meiklehill Colliery, Kirkintilloch, - 1881
Geddes, G. H., 142 Princes Street, Edinburgh, - - 1881
Gemmell, John, 96 New City Road, Glasgow, - - 1883
Gilmour, Allan, Portland Colliery, Kilmarnock, - - 1879
Glen, Robert, Eastfield Colliery, Cambuslang, - - 1881
Gordon, Gavin C., Wishaw Iron Works, Wishaw, - 1878
Grant, A. M., Townholm Engine Works, Kilmarnock, *(Councillor)*, - - - - - 1884
Gray, Archibald, Middleton House, Dalry, Ayrshire, - 1883
Gray, Archibald, 55 Eglinton Terrace, Ardrossan, - 1881
Gray, James, Riverside, Old Cumnock, - - - 1890
Gray, John, Spencerfield House, Hamilton, - - 1882
Grierson, Thomas, Glebe Colliery, Douglas, - - 1881

Haggie, P. S., Gateshead-on-Tyne, - - - 1887
Hamilton, J. B., Bourtreehill, Hamilton, - - - 1888
Hamilton, Lord, of Dalzell, Motherwell, - - - 1881
Hamilton, Robert, Derwent Villa, Crosshill, Glasgow, - 1887
Harrower, D. K., Bo'ness,- - - - - 1889
Hastie, James, Greenfield Colliery, Hamilton *(Vice-President)*, - - - - - - 1878
Hill, Alexander, 20 Rua de S. Paulo, Lisbon, - - 1883
Hill, Laurence, 2 Alfred Terrace, Hillhead, Glasgow, - 1883
Hodson, James, Liverpool Road, St. Helens, Lancashire, - 1880
Hogg, John, Orchard Street, Motherwell (*Councillor*), - 1878
Hogg, John, Victoria Engine Works, Airdrie, - - 1884
Hood, Archibald, 6 Bute Crescent, Cardiff, - - 1879

Hood, James A., Rosewell, Midlothian, - - - 1887
Hugh, James, Priory Lodge, Blantyre, - - - 1889
Hurll, Mark, Letterick Colliery, High Blantyre, - - 1880
Hyslop, Jonathan, The Cottage, Airdriehouse, Airdrie, - 1881

Irvine, C. M'Laren, Fence Colliery, Blackwood, Lesmahagow, - - - - - - 1880

Jamieson, James Auldjo, 66 Queen Street, Edinburgh, - 1885
Johnstone, Hugh, 2 Boswell Terrace, Glasgow (*Councillor*), 1879
Johnstone, Ronald H., 75 West Nile Street, Glasgow, - 1879

Keith, Daniel, Arden Lime Works, Barrhead, - - 1883
Kesson, Andrew, Roxburgh Villa, Bothwell, - - 1885

Laird, Andrew, 123 St. Vincent Street, Glasgow, - - 1883
Landale, Dr. David, The Binn, Burntisland, - - 1883
Lewin, Henry W., 154 West Regent Street, Glasgow, - 1882

M'Callum, John A., jun., 12 Waterloo Street, Glasgow, - 1887
M'Connell, J. I., Burnfoot, Sanquhar, - - - 1889
M'Creath, George W., 208 St. Vincent Street, Glasgow, - 1879
M'Creath, James, 208 St. Vincent Street, Glasgow (*Past President*), - - - - - - 1879
M'Culloch, David, Vulcan Works, Kilmarnock, - - 1885
M'Culloch, John, Loganlea Colliery, West Calder, - 1879
Macdonald, Symington, The Great Kanawha Colliery Co. (Limited), Mount Carbon, West Virginia, U.S.A., - 1880
Mackay, Andrew, Grangemouth Coal Co., Grangemouth, - 1879

M'Kenzie, Kenneth, New Bank Colliery, New Cumnock, - 1880
M'Kenzie, William, Newbattle Collieries, Dalkeith, - 1880
M'Killop, James, Slamannan, - - - - 1886
M'Kinnell, William, Clyde Steel and Iron Works, Sheffield, 1887
M'Laren, Robert, Crofthill Place, Uddingston (*Councillor*), 1882
M'Laren, William, Orchards, Bellshill, - - - 1884
M'Lauchlan, J. D., 19 St. Ninian's Terrace, Morningside Drive, Edinburgh, - - - - - 1882
M'Nab, John, - - - - - - 1881
M'Naughton, James, 11 West Regent Street, Glasgow, - 1880
M'Pherson, Gilbert, jun., Stair, Ayrshire, - - - 1887
* Marshall, R. A., 97 Bath Street, Glasgow, - - 1879
Miller, Thomas H., Vulcan Foundry, Coatbridge, - - 1885
Miller, W. M., 34 St. Andrew Square, Edinburgh, - 1889
Mitchell, George A., 67 West Nile Street, Glasgow, - 1881
* Moffat, Peter, Mount Albion, Herberton, North Queensland, - - - - - - 1881
Moore, F. W., c/o Wormald & Co., Govan, - - 1889
Moore, Robert T., 160 Hope Street, Glasgow, - - 1880
Morison, John, Newbattle Collieries, Dalkeith, - - 1879
Morton, James, Manor Park, Blairhill, Coatbridge, - 1880
Mottram, T. H., 6 Doune Quadrant, Glasgow, - - 1889
Mungall, Henry, Cowdenbeath Collieries, Cowdenbeath, - 1880
Munro, R. D., 141 Buchanan Street, Glasgow, - - 1883
Murray, Robert, Blinkbonny, Bo'ness, - - - 1889

Nasmyth, A. H., Donibristle Colliery, Crossgates, Fife, - 1880

(*) Deceased.

Neilson, George, Summerlee Iron Works, Coatbridge, - 1880
Nasmyth, J. A., Donibristle Colliery, Crossgates, Fife, - 1883
Neilson, John, Summerlee Ironworks, Coatbridge, - 1883
Nimmo, John, 12 St. Giles Street, Edinburgh, - - 1885

Oki, Yoshitada, Takasima Colliery, Nagasaki, Japan, - 1887
Ormiston, A. R., Gartness Coal Coy., 19 Waterloo Street, Glasgow, - - - - - - 1880
Ormiston, James, Mount Vernon, Glasgow, - - 1880

Park, John, Stonelaw Colliery, Rutherglen, - - 1881
Paterson, Rev. T. M. B., Ardenclutha, Hamilton, - - 1888
Patterson, A. G., Earl of Rosslyn's Collieries, Dysart, - 1886
Paul, James, 7 Shandwick Place, Edinburgh, - - 1879
Penman, Robert, 377 Dalmarnock Road, Glasgow, - 1887
Pettigrew, Robert, 66 Flowerhill Street, Airdrie, - - 1881

Rankin, John, jun., Drumgray Colliery, Airdrie, - - 1881
Rankine, David, 75 West Nile Street, Glasgow, - - 1879
Ritchie, Robert, Silver Queen Mines, Mount Zeehan, Trial Harbour, Tasmania, - - - - 1888
Robertson, David, 21 Pitt Street, Glasgow, - - 1880
Robertson, D. A. W., Metropolitan Coal Coy., Helensburgh, Illawara Line, New South Wales, - - - 1882
Robertson, Dr J. R. M., Linton, Wilson's Point, Sydney, New South Wales, - - - - 1886
Robertson, William, 123 St. Vincent Street, Glasgow, - 1879
Ronaldson, J. H., 97 Pitt Street, Sydney, - - - 1879
Roxburgh, Alexander, Alloa Coal Co., Alloa, - - 1880

Roy, William, Lauchope Colliery, Holytown, - - 1879
Russell, Archibald, jun., Avongrange, Hamilton, - - 1882
Russell, George, Summerlee Iron Works, Coatbridge, - 1883
Russell, P. B., Newfield, Hamilton, - - - 1887
Russell, Robert, Coltness Iron Works, Newmains, - 1878

Scott, William, 20 Drummond Place, Edinburgh, - - 1888
Scoular, George, Hewingham, Whitehaven, - - 1889
Sharp, Robert, Coatbridge, - - - - 1886
Smart, James, Balgreen, Hamilton (*Vice-President*), - 1879
Smith, Eustace, jun., St. Lawrence Ropery, Newcastle-on-Tyne, - - - - - - 1885
Smith, George W., Port Elizabeth, South Africa, - - 1883
Smith, James, Saracen Colliery, Possil, - - - 1884
Stafford, Thos. W., 1 Lea Road, Heaton Chapel, Stockport, 1885
Stevenson, Hugh, 21 Clyde Place, Glasgow, - - 1884
Stewart, Alex., Tharsis Mines, Huelva, Spain, - - 1879
Strain, Hugh, jun., Rigg Colliery, Airdrie, - - 1887

Terris, Henry, Clackmannan Colliery, Clackmannan, - 1880
Thomson, Charles, Calder Iron Works, Coatbridge, - 1879
Thomson, David, Craigderran House, Cardenden, - - 1887
Thomson, Thomas, 38 New Row, Dunfermline, - - 1884
Thorneycroft, Wallace, Merryton Colliery, Hamilton (*Councillor*), - - - - - 1887
Thornton, Peter, Crofthead, Fauldhouse, - - - 1878
Todd, John, Wellshot, Kilsyth, - - - - 1888
Torrance, James W., 81 St. Vincent Street, Glasgow, - 1881
Tweedie, James A., 12 St. Andrew Square, Edinburgh, - 1887

Waddell, Robert, 11 West Regent Street, Glasgow, - 1880
Waldie, James F., 53 Waterloo Street, Glasgow, - - 1883
Walker, James, 66 Waterloo Street, Glasgow, - - 1883
Walker, James P., Dalmellington Iron Works, Ayrshire, - 1880
Walker, William H., Springwells Colliery, Airdrie, - 1880
Wallace, James, Wester Gartshore Colliery, Kirkintilloch, 1882
Watson, John, Earnock, Hamilton, - - - 1879
Watson, William, Bank Street, Coatbridge, - - 1886
Weir, Alexander, Fireclay Works, Castlecary Station, - 1881
Whitelaw, Thomas, Dalzell Colliery, Motherwell, - - 1879
Whyte, Robert, 15 Gordon Street, Glasgow, - - 1887
Wilson, Andrew, Dalzell Estate Office, Motherwell, - 1880
Wilson, John, Alderston, Mid-Calder, - - - 1881
Wilson, John, 69 Great Clyde Street, Glasgow, - - 1879
Wilson, Robert M., Anchorage, Bothwell, - - 1889
Wood, James, 40 St. Enoch Square, Glasgow, - - 1880
Wylie, John, Clifton Iron Works, Coatbridge, - - 1883

Yates, Andrew, Grange Colliery, Kilmarnock, - - 1881
Young, John, Baljaffray Colliery, New Kilpatrick, - 1881
Young, Robert, 37 West George Street, Glasgow, - - 1882
Young, Robert, 42 Bath Street, Glasgow, - - - 1888
Young, William, 204 Stobcross Street, Glasgow, - - 1885

ORDINARY MEMBERS.

Subscripton, 10s 6d.

Addie, Alexander, 67 Johnston Street, Airdrie, - - 1888
Addie, William, Summerlee Iron Works, Coatbridge, - 1889
Allan, John, Calder Iron Works, Coatbridge, - - 1881
Allan, William, Woodyett and Dennymill Mines, Denny, 1881
Allardice, James, Eastfield Colliery, Cambuslang, - - 1881
Anderson, David, Cowdenbeath Colliery, Cowdenbeath, - 1881
Anderson, George, - - - - - 1880
Anderson, George, Ferniegair Colliery, Hamilton, - 1885
Anderson, John, Lochgelly Iron and Coal Coy., Lochgelly, 1880
Andrew, Robert, Minas de Aznacollar, Seville, Spain, - 1880
Andrew, William, Lassodiè Colliery, Dunfermline, - 1880
Archibald, David, Pentland Mines, Loanhead, - - 1888
Archibald, William, Pentland Oil Works, Loanhead, - 1879

Bain, James, Brownrigg Colliery, Longriggend, - - 1889
Baird, Dugald, Leven Collieries, Leven, - - - 1887
Baxter, Robert, Niddrie Collieries, Portobello, - - 1880
Beaton, Henry, Balbardie Colliery, Bathgate, - - 1889
Beith, Robert, Loanhead Colliery, Loanhead, - - 1878
Bell, Alan D., 123 St Vincent Street, Glasgow, - - 1890
Benson, James R., West Longrigg, Airdrie, - - 1887
Beveridge, David, Kirkness Colliery, Lochgelly, - - 1888
Beveridge, James, Linlithgow Oil Coy., Linlithgow, - 1882
Beveridge, John, Kelty Colliery, Blairadam, - - 1881
Birrell, George, 2 Havelock Terrace, Paisley Road, Glasgow, - - - - - - 1880

Blackwood, James, Albany Place, Hamilton *(Librarian)*, - 1887
Blyth, Archibald, Bent Colliery, Hamilton *(Treasurer)*, - 1878
Bowie, Hunter, Lugar Iron Works, Old Cumnock, - 1881
Bowser, C. H., 13 Royal Crescent, Glasgow, - - 1885
Brown, George, Longriggend Colliery, Airdrie, - - 1880
Brown, John, Doura, Irvine, - - - - 1888
Brown, Robert, Drumpellier Colliery, Coatbridge, - 1883
Brown, Peter, Martin's Crescent, Airdrie, - - 1881
Brownlie, Archibald, Lassodie Colliery, Dunfermline, - 1883
Bryden, David, Coylton, Ayr, - - - - 1881
Buchanan, John, Palacecraig Colliery, Airdrie, - - 1887
Burt, Hutchison, Cardenden Colliery, Lochgelly, - - 1885

Cairns, William, Muiredge Colliery, Buckhaven, - - 1887
Caldwell, James, Pumpherston, Mid-Calder, - - 1887
Campbell, Alexander, Bellfield Colliery, Hurlford, - 1882
Campbell, James, Burnside Row, Auchinleck, - - 1889
Campbell, John, Hollandbush, Bonnybridge, - - 1888
Campbell, Thomas, Spindleside Colliery, Omoa, Motherwell, - - - - - - 1881
Carey, William, Grange Colliery, Bo'ness,- - - 1882
Carmichael, Robert, Earnock Colliery, Hamilton,- - 1880
Clark, John, Arniston Colliery, Gorebridge, - - 1888
Clark, William, 208 St Vincent Street, Glasgow, - - 1883
Clarke, J. A., Ayr Colliery, Ayr, - - - - 1880
Clelland, James, Carronhall Colliery, Falkirk, - - 1879
Cochrane, Joseph, Tippiecanoe, Fayette Co., Pa., U.S.A.,- 1883
Cochrane, Neil, Glasgow Canadian Phosphates Co. (Ltd.), Buckingham, Ottawa, Canada, - - - 1881

Cowan, James, Cadzow Colliery, Hamilton, - - 1885
Cranston, David, Woodend Colliery, Armadale, - - 1880
Crichton, A. H., Hillside, Linlithgow, - - - 1880
Crockett, John D., Curran House, Dungannon, - - 1880
Crookston, Andrew, Wemyss Colliery, Dysart, Fife, - 1880
Crookston, Thomas, Kelty Bridge, Blairadam, - - 1879
Cunninghame, Archibald, Eglinton Iron Co., Dalry, - 1881
Cuthbert, Robert, Westrigg Colliery, Armadale, - - 1881

Danks, Henry, Green Colliery, Wishaw, - - - 1880
Davies, William, Barncluith Colliery, Hamilton, - - 1887
Dewar, Robert, Harthill Colliery, Whitburn, - - 1881
Dewar, Thomas, Glencleland Colliery, Wishaw, - - 1881
Dick, James, Drumsmudden Colliery, Drongan, - - 1889
Draper, William, Seaham Colliery, Sunderland, - - 1890
Drinnan, John, Wishaw Coal Coy., Motherwell, - - 1880
Drinnan, Walter, Shotts Iron Works, Shotts, - - 1888
Dron, Robert W., Earnock Colliery, Hamilton, - - 1888
Dunsire, Andrew, Cameron Colliery, Windygates, - 1883

Easton, Alexander, 13 South Bridge Street, Bathgate, - 1883
Easton, Alexander, Hope House, Cleator Moor, Cumberland, - - - - - - - 1888

Faulds, Alexander, Melbourne Villa, Cambuslang, - 1878
Ferguson, David, Minas de Aznacollar, Seville, Spain, - 1878
Ferguson, Duncan, Lochore and Capeldrae Collieries, Lochgelly, - - - - - - - 1880
Ferguson, William, Byrehill Row, Kilwinning, - - 1887

Findlay, Hugh, 78 Hill Street, Kilmarnock, - - 1886
Fisher, Robert, Bowthorn Colliery, Cleator Moor, Cumberland, - - - - - - 1888
Forbes, Alexander, Allanton Colliery, Hamilton, - - 1885
Foster, John W., 6 North St. Silksworth Colliery, Sunderland, - - - - - - 1889
French, John, Millcroft Cottage, Rutherglen Road, Glasgow, 1879
Frew, James, 5 Greenhill, Waterside, Ayr, - - 1887
Frew, William, Barncluith Colliery, Hamilton, - - 1887
Frew, William, Quarter Colliery, Hamilton, - - 1887
Fulton, David, Dalquharran, Maybole, - - - 1881

Gardner, Hugh, 160 Hope Street, Glasgow, - - 1890
Gavin, James, Udston Colliery, Hamilton, - - 1880
Gibb, Robert, Daldowie Colliery, Broomhouse, - - 1887
Gibson, William K., Carron Wharves, 87-93 Lower E. Smithfield, London, E., - - - - 1886
Gilchrist, James, Earnock Colliery, Hamilton (*Councillor*), 1878
Gilchrist, John, 2 Old Terrace, Muirkirk, - - - 1888
Gillespie, Alexander, Dalmellington Iron Works, Ayr, - 1889
Gilmour, James, Duchray Colliery, Coylton, Ayr, - 1881
Goodwin, George, Gun Place, Woodside Street, Coatbridge, 1885
Graham, Hugh, Shotts Iron Works, Shotts, - - 1888
Grahame, John, - - - - - - 1887
Grant, John, Bog and Home Farm Collieries, Larkhall, - 1878
Gray, David, Chapel Colliery, Newmains, - - 1885
Gray, John, Shotts Iron Works, Shotts, - - - 1885
Gray, William, Common Cottage, Auchinleck, - - 1880
Gray, William, Carfin Colliery (Dixon's), Motherwell, - 1885

Green, William, Galston Colliery, Galston, - - 1883
Greig, James, Arden Works, Airdrie, - - - 1887

Haddow, John, Arniston Colliery, Gorebridge, - - 1879
Hamilton James, 208 St. Vincent Street, Glasgow, *(Councillor)*, - - - - - 1883
Hamilton, John P., 34 Cadogan Terrace, S.W., London, - 1888
Hamilton, William, - - - - - 1888
Hardie, James, Hopetoun, Winchburgh, - - - 1882
Hart, John, Clyde Iron Works, Tollcross, - - - 1881
Hart, Robert, - - - - - - 1887
Henderson, Andrew, Gartsherrie Colliery, Coatbridge, - 1880
Henderson, William, Levenseat, Fauldhouse, - - 1884
Herd, Samuel, Balgonie, Markinch, - - - 1885
Herd, Thomas, Dunnikier Colliery, Kirkcaldy, - - 1880
Heron, James, Auldhouseburn Colliery, Muirkirk, - 1888
Hill, James, Dalmellington, - - - - 1880
Hillhouse, William, Bonnyton Cottage, Kilmarnock, - 1883
Hogg, James, Kirkhill Colliery, Cambuslang, - - 1887
Hogg, William, Carnmoor Cottage, Forth, by Lanark, - 1881
Howat, John T., Eglinton Iron Works, Kilwinning, - 1883
Howat, Robert M., Bardykes Colliery, Newton, - - 1886
Howat, William, Morningside Colliery, Newmains, - 1886
Howat, William, Southrigg Colliery, Armadale, - - 1886
Hunter, Adam, Braidenhill Colliery, Airdie, - - 1885
Hunter, A., Alloa Colliery, Alloa, - - - - 1880
Hunter, Andrew, Orbiston Colliery, Bellshill, - - 1878
Husband, John, Tannochside, Uddingston, - - 1881

Ireland, Thomas, Largoward, St. Andrews, - - 1881

Jackson, Douglas, Ross Colliery, Hamilton, - - 1880
James, William, Fordell Colliery, Crossgates, Fife, - 1883
Jamieson, Alexander, Balgonie Colliery, Markinch, - 1878
Jamieson, William, Rosebank Cottage, Broxburn,- - 1879
Jeffrey, William, Ladylands Colliery, Shotts, - - 1888
Johnstone, William, Coaltown of Wemyss, E. Wemyss, - 1888

Kennedy, Alexander, Broxburn Oil Works, Broxburn, - 1882
Kennedy, William, Whiteside Lane Cottage, Bathgate, - 1888
Kerr, Archibald, Barncluith Colliery, Hamilton, - - 1881
Kerr, Archibald, Bankend Colliery, Lesmahagow,- - 1881
Kerr, Thomas, Netherjohnstone Colliery, Wishaw, - 1888
Kerr, William, Barncluith Colliery, Hamilton, - - 1885
King, Henry, Darngavil Colliery, Airdrie, - - 1889
Kirkwood, William, Blackstone Works, Paisley, - - 1880
Kirkwood, Wm. A., Clydeview, Larkhall, - - 1890
Knox, James, Tranent Collieries, Tranent, - - 1880

Lander, Francis, Oakbank Oil Works, Mid Calder, - 1885
Legat, A. S., 26 N. Hamilton Street, Kilwinning, - 1879
Lindsay, Thomas J., Castlehill Iron Works, Carluke, - 1885
Lithgow, Thomas, Langbyres Colliery, Omoa, Motherwell, 1882
Livingstone, Archibald, Banknock Colliery, Bonnybridge, 1880
Love, John, Shottstown, Penicuik, - - - 1878
Love, John, Portland Iron Works, Hurlford, - - 1882
Love, William J., Shotts Iron Coy., Shotts, - - 1881

M'Beth, Peter, Callander Coal Co., Falkirk, - - 1879

M'Bride, John, South Lodge, Rawyards, Airdrie, - - 1889
M'Cann, Edward, 9 Westpans, Musselburgh, - - 1888
M'Culloch, John, Jawcraig Colliery, Slamannan, - - 1888
M'Culloch, William, Linkieburn House, Muirkirk, - 1881
M'Donald, John, Greenhill Colliery, Holytown, - - 1880
Macfarlane, Nigel, Blantyre, - - - - 1890
M'Farlane, Walter, Mossvale Cottage, Chryston, - - 1882
M'Gee, John, Tillicoultry Colliery, Tillicoultry, - - 1880
M'Gill, James, Burntisland Oil Works, Burntisland, - 1887
M'Kay, James, Roughrigg Colliery, Airdrie, - - 1880
M'Kenzie, Daniel, - - - - - 1886
M'Neil, James, Glencleland House, Wishaw, - - 1878
M'Phail, James, North Motherwell Colliery, Motherwell, 1884
M'Pherson, Gilbert, Holmes Colliery, Galston, - - 1881

Malcolm, James, Haywood Colliery, Lanark, - - 1879
Marshall, John, Seymore House, Stevenston, Ayrshire, - 1888
Martin, Robert, Westburn Colliery, Newton, - - 1879
Martin, William, Douglas Park Colliery, Bellshill, - 1881
Mathie, James, - - - - - - 1879
Menzies, John, Gilmerton Colliery, Edinburgh, - - 1889
Middleton, George, Neilston Colliery, Kilsyth, - - 1886
Miller, John D., Langloan Iron Works, Coatbridge, - 1888
Miller, William, 80 High Street, Loanhead, - - 1883
Milligan, Peter, Cleland, - - - - - 1884
Moffat, James, 34 West-End Cottages, Loanhead, - 1888
Moodie, Thomas, Devon Colliery, Alloa, - - - 1881
Moore, Robert, Pumpherston, Mid-Calder, - - 1888
Morton, John, Bellfield Colliery, Hurlford, - - 1880

Morton, R. M., Ansonhill House, Crossgates, Fife, - 1879
Morton, William S., Skaterigg Colliery, Maryhill, - 1884
Mowat, David M., Summerlee Ironworks, Coatbridge, (Councillor), - - - - - 1886
Muir, Robert, Bog Colliery, Larkhall, - - - 1887
Muir, W. W., Coltness Colliery, Newmains, - - 1878
Munro, James, Quarter Collieries, Hamilton, - - 1879
Munro, Neil, Twechar, Kilsyth, - - - - 1886

Nasmyth, A., Donibristle Colliery, Crossgates, Fife, - 1880
Neilson, Benjamin, Prestongrange Coal Coy., Prestonpans, 1880
Ness, Henry, Benarty Colliery, Blairadam, Kelty, - 1880
Nimmo, Thomas, Kinneil Colliery, Bo'ness, - - 1879
Nisbet, Andrew, Carfin Colliery, Motherwell, - - 1884
Nisbet, Henry, Alloa Colliery, Alloa, - - - 1888
Nivison, John, Dykehead Colliery, Larkhall, - - 1886

Orr, Thomas, Bredisholm Colliery, Uddingston, - . 1881

Park, James, Wellhouse, Rutherglen, - - - 1883
Prentice, Wm. P., Dalmeny Works, Dalmeny, - - 1889
Paterson, Peter, 1 Cambusnethan Street, Wishaw, - 1889
Park, Joseph, Allanshaw Colliery, Hamilton, - - 1878
Parker, William, Woodville Cottages, Armadale, - - 1887
Paterson, Hugh, Braidhurst Colliery, Motherwell, - 1881
Paterson, Thomas, 208 St. Vincent Street, Glasgow, - 1883
Paul, James, Law Colliery, Carluke, - - - 1881
Penman, James, Leven Collieries, Leven, - - 1883
Pearson, Andrew, Priestfield, Blantyre, - - - 1889
Peddie, J. F., 15 Oxnam Crescent, Newcastle-on-Tyne, - 1889

Pitcairn, James S., - - - - - 1885
Plunkett, Edmund, Punjour Gold Mines, Singapore, - 1889
Potts, Samuel, Greenfield Foundry, Hamilton, - - 1888
Powell, Evan, - - - - - - 1888
Prentice, James, Stanrigg Collieries, Airdrie, (*Councillor*), - 1881
Prentice, Thomas, Brisdanehill, West Calder, - - 1879

Rankin, George, Victoria Works, Nitshill, Hurlet, - 1889
Ritchie, James, Gartness Colliery, Airdrie, - - 1885
Roberts, James, Holmes Cottages, Uphall, - - 1889
Robertson, Alex., Benwhat, Dalmellington, - - 1880
Robertson, Archd., Bathville Colliery, Armadale, - 1880
Robertson, David, Dalquharran Colliery, Maybole, - 1881
Robertson, James A., 54 Blacket Place, Edinburgh, - 1885
Robertson, John, Lanemark Colliery, New Cumnock, - 1880
Robertson, Richard, Rhins Houses, Baillieston, - - 1887
Robertson, Thomas, New Lodge, Slamannan, - - 1890
Robson, Robert, Sydney Mines, Cape Breton, Nova Scotia, 1882
Rodger, Alexander L., Tharsis Mines, Huelva, Spain, - 1884
Rodger, William, Fergushill Colliery, Irvine, - - 1888
Rome, J. E., Thistle Cottage, Longridge, Fauldhouse, - 1886
Rorison, John, Springhill Colliery, Kilmarnock, - - 1883
Ross, Michael, Dechmont Colliery, Newton (*Councillor*), - 1878
Rowan, Donald, Harthill, Whitburn, - - - 1884
Rowan, Henry, Hill of Beath Colliery, Crossgates, - 1881
Roy, Henry, Legbrannoch Collieries, Holytown, - - 1889
Roy, John, Fireclay Works, Castlecary Station, - - 1888
Roy, Robert P., Mount Carron, Larbert, - - - 1889
Russell, Andrew, 97 Melville Drive, Motherwell, - - 1887

Russell, Charles, Westrigg Colliery, Armadale Station, - 1886
Russell, Joseph, Daldowie Colliery, Broomhouse, - - 1889
Russell, W. S., Machan, Larkhall, - - - 1880

Salmond, James, Barncluith Colliery, Hamilton, - - 1888
Scobie, William, Gilbertfield Colliery, Cambuslang, - 1881
Scott, John, Calder Iron Works, Coatbridge, - - 1879
Seggie, James, - - - - - - - 1885
Semple, William, sen., Goatfoot Colliery, Galston, - 1881
Sharpe, George, Wilsontown Colliery, Lanark, - - 1881
Shearer, James, - - - - - - 1888
Shore, Wm. M., Kaitangata, Dunedin, New Zealand, - 1886
Simpson, Alex., Knockterra Cottage, Cumnock, - - 1889
Simpson, Dundas, Ellismuir Colliery, Baillieston, - 1879
Simpson, Robert, Auchter House, Newmains, - - 1888
Smith, David, Dalmellington Iron Works, Ayr, - - 1885
Smith, David L., Barr Colliery, Beith, - - - 1888
Smith, Hamilton, Cadzow Colliery, Hamilton, - - 1878
Smith, James, Hallhill Colliery, Baillieston, - - 1881
Smith, John, Cannock Lodge Colliery, Bloxwich, Staffordshire, - - - - - - 1878
Smith, John, Rosehall Colliery, Coatbridge, - - 1880
Sneddon, James B., Argyll Colliery, Campbeltown, - 1886
Sneddon, Robert, Millpark Cottage, West Calder, - 1888
Somerville, William, Bothwellpark Colliery, Bellshill, - 1880
Speir, William, Balgonie Colliery, Thornton, - - 1888
Speirs, Adam, Westmains Cottage, Bathgate, - - 1888
Stark, Archd., Orchardhead Cottage, High Blantyre, - 1888
Stevenson, Wm., Aitken's Buildings, Rawyards, Airdrie, - 1888

Stewart, H., Muiravonside Colliery, Slamannan, - - 1881
Stewart, Robert, Legbrannock Collieries, Holytown, - 1883
Stirling, John, Bonnybridge, - - - - 1880

Telfer, Henry, Overtown Colliery, Wishaw, - - 1878
Thom, Archibald, Moresby Coal Coy., Whitehaven, - 1881
Thom, James R., Bothwell Collieries, Bothwell, - - 1887
Thomson, A. M'D., Raith Colliery, Cowdenbeath,- - 1880
Thomson, George, Fauldhouse Works, Fauldhouse, - 1884
Thomson, James, Ross Street, Dunfermline, - - 1883
Thomson, John, Foulford Colliery, Cowdenbeath,- - 1888
Thomson, Richard, Queen's Buildings, Lenzie, - - 1878
Thomson, Thomas, Arnloss Cottage, Slamannan, - - 1879
Turner, William, Chapel Colliery, Newmains, - - 1881
Twaddle, William, Ferniegair, Hamilton, - - - 1878

Waddell, Alexander W., 37 Burnbank Gardens, Glasgow, 1883
Waldie, A. B., 25 Douglas Crescent, Edinburgh, - - 1885
Walker, David, Dalzell Colliery, Motherwell, - - 1880
Walker, David, jun., Bathville Collieries, Armadale, - 1884
Walker, George B., Tankersley Grange, Barnsley, - 1887
Walker, Robert, Bog Colliery, Larkhall, - - - 1881
Walker, William, Cadzow Colliery, Hamilton, - - 1887
Walker, John W., Woodmuir Colliery, West Calder, - 1889
Walker, William, Rigside Colliery, Douglas, - - 1880
Wardlaw, John, Garriongill Colliery, Wishaw, - - 1878
Wardlaw, Robert, Crofthead Colliery, Fauldhouse, - 1883
Wardrope, James, Ormiston Station Colliery, Ormiston, - 1887
Watt, Robert, Barncluith Colliery, Hamilton, - - 1887

Webster, David, Burdiehouse Lime Works, Edinburgh, - 1880
Weir, Robert, Seaview Cottage, Grangemouth, - - 1889
Weir, William, Equitable Coal Co., Deshergar Barakar, E.I. Railway, Bengal, - - - - 1884
White, James, 70 Fullarton Street, Irvine, - - 1885
Whiteside, John, Ballochmyle Colliery, Auchenleck, - 1888
Wilkie, William, South Arnloss Colliery, Slamannan, - 1885
Williams, W. H., Shag Point Colliery, Shag Point, Otago, N.Z., - - - - - - 1888
Williamson, James, Dunbeth Terrace, Coatbridge, - 1880
Williamson, William, 64 Beckford Street, Hamilton, - 1886
Wilson, Robert, Longrigg Colliery, Slamannan, - - 1880
Wilson, Robert, Eastgrange Cottage, Dunfermline, - 1880
Wilson, William, Auchinraith Colliery, High Blantyre, - 1879
Wingate, John B., 208 St. Vincent Street, Glasgow, - 1890
Wood, Thomas, Pentland Works, Loanhead, - - 1887
Wylie, James, Townhill Colliery, Dunfermline, - - 1880
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DUTY TRIALS OF PUMPING ENGINES.

By J. S. COON. Page 476.

PURCHASERS of pumping engines often stipulate that they shall give a certain "duty" before they are taken off the contractor's hands; and in cases in which the duty is likely to fall short, disputes sometimes arise between the builders and the experts making the trials as to the allowance to be made for certain things—as to whether the duty is to be calculated on the actual quantity of water delivered, or on the plunger displacement; whether any allowance should be made for the friction of water in the pump passages and pipes; and in the case in which the boilers are not supplied by the same contractor, and the evaporation of so many pounds of water is fixed as being equivalent to the combustion of one pound of coal; as to whether the pound of coal is to be taken as the equivalent of the water evaporated from the temperature of the feed water in the pond; also as to whether only dry steam should be charged against the engines, and also as to what allowance, if any, should be made for steam consumed by the feed pump engine. The methods of guaging the condition of the fires at the beginning and end of the trials are open to variation in the practice of different individuals, and the reports are not made so that a fair comparison can be instituted between different engines. "Without doubt," the author concludes, "many of these unsatisfactory features are due to the fact that duty trials are often conducted by civil engineers whose training and experience does not qualify them for expert work of this character, and such tests, while they may be perfectly sincere, cannot be regarded as authoritative." The practical result of his paper is the appointment of a committee to draw up rules with the object of forming a uniform practice in conducting duty tests. J. G.

Transactions of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Vol. IX.

WIRE ROPE FASTENINGS.

By WILLIAM HEWITT. Page 671.

IN this paper a description is given of the behaviour of the fastenings which were employed in making tests of wire ropes. When using ordinary spliced-in thimble it was found that the strain elongated the thimble, forced one end past the other, which cut one or more of the strands so that the rope almost invariably broke in one of the splices. With conical sockets the rope pulled out under a strain varying from one-half to three-fourths of the breaking load. A cast steel rope, two inches in diameter, was tested with socket fastenings prepared in the usual way with the addition of an annular wedge driven in around the core, with the result that the wires pulled out of the socket about three-quarters of an inch, and the rope then broke under a load of 266,250 pounds, being 71½ per cent. of the tensile strength of the individual wires of which it was made. The method of capping ropes in Britain is noticed, and it is suggested that the fastening might be made more secure by employing nuts to force up the rings which surround the joint. J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. XCIV.

ON AN UNDERGROUND PUMPING ENGINE AT THE BERNISSART COLLIERY.

By A. LEDENT. Foreign Abstracts, Page 374.

GREAT improvements have recently been effected in high speed pumping engines working under considerable heads. The advantages of engines of this class are economy of first cost and maintenance, and also of steam, and the power of dealing with exceptional influxes by increasing the working speed. A smaller rising main and the suppression of pump spears save shaft room, and the liability to accidents is reduced. But against these advantages must be set the risk of having the pump drowned, which is sometimes guarded against by water-tight bulkheads and sluices.

The engine is stationed at a depth of 131 fathoms, and has two

horizontal cylinders, 17¾ inches diameter by 35½ inch stroke, coupled at right angles to a shaft with a 4-ton fly-wheel. Four single acting plungers, each 4½ inches diameter, are driven from the tail rods of the pistons at a speed of 43 revolutions per minute. The valve gear is a modification of the Meyer gear, and the average point of cut-off is about 1-7th of the stroke. The whole of the water pumped is passed through the condenser, water and steam flowing through a pipe pierced with 360 ¼-inch holes, and the air-pump draws directly from the sump. "The pump barrels are of a special ovoidal form, the cross-section at each point of their length corresponding with the relative speed at the same position of the plunger end, which is of a convexo-concave contour, so that the speed of the displaced particles of water is always uniform, and in the return stroke the water follows up the plunger from all sides without any vacuum or consequent concussion." The rising main is 6½ inches diameter, and the pressure does not vary more than 7 lbs. per square inch at the bottom. The steam pipes are 4 inches bore, and the boiler pressure of 55 lbs. at the surface sinks to 52 lbs. per square inch at the pit-bottom. It is claimed that the useful effect of the pumps is 80 per cent. of the theoretical value. J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. XCIV.

VARIETIES OF CLAY, AND THEIR DISTINGUISHING QUALITIES FOR MAKING GOOD PUDDLE.

By WILLIAM GALLON. Page 231.

"ANY substance formed of minute particles of decomposed, earthy material, which, when worked up with water, becomes plastic or capable of being moulded, is commonly called clay." The purest form contains the largest proportion of alumina, and analyses of different kinds show from 46 to 66 per cent. of silica, 22 to 38 per cent. of alumina, and from 5 to 13 per cent. of water, together with small quantities of oxide of iron and lime—to the former of which the colour is mostly due—and traces of magnesia. The plasticity of clay results from the combination of water with the silicate of alumina; the part of the water which is held in the pores may be driven off at 212° F., but the remainder only after prolonged exposure to a very high temperature, such as that used in burning bricks, when the clay is deprived of its plasticity, and shrinks in proportion to the quantity of water expelled.

Puddle is of considerable importance in engineering works, and the essential condition is that it should be tenacious enough to be impervious to water; and most clays, when free from coarse, gritty impurities, contain sufficient alumina to fulfil this condition ; but it is requisite that the clay should be tempered and worked up with sufficient water to fill every pore. This tempering is greatly facilitated by exposure to the atmosphere, which also reduces the labour of working up by cutting, cross-cutting, poaching with a tool, and treading. Puddle, from its position, is usually protected from evaporation, but if placed near the surface the addition of sand may be necessary to diminish its cohesiveness and prevent its contraction and the consequent formation of fissures.

"The tenacity of a clay may be tested by working up a small quantity with water into a thoroughly plastic condition, and forming it by hand into a roll about 1 to 1½ inch in diameter by 10 to 12 inches in length. If such a roll is sufficiently cohesive not to break on being suspended from one end when wet, the tenacity of the material is ample. To test its power of retaining water, 1 to 2 cubic yards of the clay should be worked with water by the usual methods to a compact, homogenous, plastic condition, and then a hollow should be formed in the centre of the mass capable of holding four or five gallons of water. After filling the hollow with water, it should be covered ever to prevent evaporation, and left for about twenty-four hours, when its capability of retaining water would indicate its suitability or unsuitability for making puddle." J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS.
Vol. XCIV.

ON A MOVABLE PLATFORM FOR INCLINED PLANES IN MINES.

By CHARLES RUIDANT. Foreign Abstracts, Page 377.

The object of this arrangement is to make connection between the rails of steep inclined planes, worked by engine power, and those of intermediate level roads which branch off them to each side. It consists of an angle iron frame having two horizontal top bars, one on each side of the incline rails, and at the same level as the branch road rails. On one of the top bars is hinged a malleable iron plate after the manner of a trap door in a floor. When this plate is in a vertical position, in which it is kept by a counter-balance weight, it blocks the branch road, and the trains on the incline are free to pass up and down. When the plate is lowered to a horizontal position, it rests on both of the top bars, and its upper end touches the incline rails, and so forms a connection between the branch road and the incline. J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS.
Vol. XCIV.

ROUX'S HYDRAULIC PUMP.

By A. BRÜLL. Foreign Abstracts, Page 367.

AT the Creusot coal mines the main source of the water is at a depth of 1153 feet, but a considerable quantity comes into the shaft at a level 279 feet higher. Water falling through the latter distance is capable—allowing 40 per cent. of efficiency in the lifting machinery—of raising one-tenth of its volume to the shaft top; and it was proposed to put in a Roux pump for this purpose, in order to relieve the ordinary pumping engines, which were already working up to the limit of their capacity. "Mr Roux's apparatus consists of a large air vessel, beside which are placed, on either side, two horizontal pumps, which may be worked together or separately. In each pump three pistons are at work. Being cast together in one piece, they reciprocate simultaneously. The central piston is 14 inches in diameter, is double acting, and forms the motor. The outer pistons are about 5½ inches in diameter, are single acting, and have a common stroke of 10 1-5th inches. A valve-box at the outer end of each single-acting pump contains a suction valve and a delivery valve. By the smaller pistons the water is forced up the shaft. There are no piston-rods or stuffing boxes. The distribution of water pressure is effected by means of a species of piston-valve, which reciprocates by the pressure of the water, in a cylinder about 3¼ inches in diameter, placed above and parallel to the motor. A second valve, about 1½ inches in diameter, is placed over the large valve, and it is by the reciprocations of this smaller valve that those of the larger valve are effected. The motion of the smaller valve is produced by a small current of water from the working cylinder, through orifices which are uncovered by the piston a little before the end of each stroke. The supply pipe is 8 inches in diameter; that for the lift is 5½ inches."

The machine is driven at a speed of 50 double strokes per minute, and shows an efficiency of 70 per cent.; has worked more than a month at a time without being inspected, and has even been running for many days under 25 feet of water. J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS.
Vol. XCIV.

A COAL MINE 3280 FEET DEEP NEAR CHARLEROI.

By M. LEMAY. Page 378, Foreign Abstracts.

THIS shaft, called St. Andre, is only 10 feet in diameter, was commenced in 1834, and has now reached a depth of 513 fathoms, which is the lowest

level at which coal is worked. The depth to the bottom of the sump is 522 fathoms, but the water flowing into it is not more than 3 gallons per minute. The pit is equipped for a depth of 547 fathoms, and probably from this is derived the figures in the title of the paper. The ropes, which are of flat steel, 4 1-10th inches by ¾ inch, weigh 17 lbs. per yard, and are wound on a drum having an initial diameter of 14 feet. The cages have six decks, each carrying one tub. Cage and load together weigh 6½ tons, and together with the rope makes a total lift of 14¼ tons at the start.

At the bottom of the pit, the air, travelling at the rate of 6½ feet per second, has a temperature of from 59° to 64° F. In the interior of the workings, however, the temperature reaches 77° in the headings, and even 90° in the cul-de-sacs. The author concludes, from the results obtained in this pit, that under ordinary conditions mining at great depths is quite feasible. J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. XCIV.

THE NEW EXPLOSIVE BELLITE.

By P. F. CHALON. Foreign Abstracts, Page 391.

THE inventor, Carl Lamm, experimented with it in the Argenteuil quarries. It is composed of from four to five parts of ammonium nitrate and one part of dinitro-benzene. A 2 1-5th lb. cartridge of compressed bellite placed on a block of stone was exploded with a detonatar of 7¾ grains of fulminate of mercury. The block was broken. Five 1½-inch holes, from 2 to 11½ feet long, having charges of from 1 oz. to 2¾ lbs. rammed hard, gave results tending to show that bellite acts like a good slow powder in blasting, and does not crush up the rock. 1 1-10th lb. of bellite in a tin box, placed between two iron rails, 2¾ feet long, were by its explosion shattered into minute fragments, and it was estimated that 3 ozs. were sufficient to break a rail. A 55 lb. shell, containing 3½ lbs. of the substance, was shattered on explosion into about 350 pieces. Five pounds of bellite, buried 5 feet deep in the ground, projected a shower of earth 26 to 33 feet into the air, and the diameter of the funnel formed was 11½ feet at the widest point. Pieces of the new powder, hit with a heavy hammer, were crushed without exploding, and handfuls thrown upon the fire melted and fused without detonation. It is stated that "its gradually increasing effect, like the best slow powders, will render it very valuable for coal-mining; and it is probable that, owing to the large proportion of ammonium nitrate in its composition, it will produce very little flare on blasting." J. G.

Minutes of Proceedings of the INSTITUTION OF CIVIL ENGINEERS. Vol. XCIV.

A NEW METHOD OF STOCKING AND RELOADING COAL.

By JAMES M. DODGE. Page 270.

THE stocking is accomplished by means of an endless chain carrying flights or scrapers, eight inches by twenty inches, spaced two feet apart on the chain, which passes over a sprocket wheel, situated under the railway from which the coal is discharged, and around a traction wheel secured to the upper end of a vertical guyed pole, fifty to seventy-five feet in height, and distant from the railway from one hundred to two hundred feet. For the lower part of the chain there is no support between the foot and head wheels, but the return portion is borne up by idler wheels, at intervals of fifty feet, suspended from wire cables or supported on light trestle work. The flights on the chain scrape the coal from the place where it is tipped up the face of the heap, forming a conical pile with its apex under the chain, until it ultimately takes the shape of a bing "sixty-five feet high and three hundred feet across its base, and containing about twenty thousand tons." The apparatus is stated to have a capacity of two tons per minute, and four machines are in use at the wharves of the Philadelphia and Reading Railway Company, who bargained that the contract for the new stocking system should pay for all breakage of coal in excess of their previous average. When the coal is carried up at an angle of one in two, pieces of old boiler plate are laid down every ten to fifteen feet "with the round side up" so as to ease the scrapers; and when it has to be carried up at a much higher angle, troughs with high sides require to be used for the scrapers to work in, and it is stated in the discussion that at the mines these troughs are from eight to twenty-four inches wide, and rise seven inches to the foot, and that the wear of the coal in them was very slight.

The stock is reloaded into wagons by a conveyor, which is pivoted at the railway loading place, and is moved sideways on to the pile, and carries the coal into an inclined conveyor, which elevates it to a loading hopper, from which it is discharged into the trucks. J. G.

Transactions of the AMERICAN SOCIETY of CIVIL ENGINEERS. Vol. XIX.

PLANT AND MATERIAL OF THE PANAMA CANAL.

By WILLIAM PLUMB WILLIAMS. P. 273.

IN the spring of 1888 Mr Williams travelled over these works from Colon to Panama, making a slow and careful examination, extending over five weeks, gathering information from engineers, contractors, foremen, and workmen.

All the plant belongs to the Canal Company, and is leased to the different contractors at 8 per cent. per annum on its value, a system which appears to be bad, as the contractors have no inducement to take care of the machinery placed at their disposal, and for the least defect expensive excavators, rock drills, cranes, locomotives, and hoisting engines are thrown aside.

When the works commenced the shops of France and Belgium could not supply the machinery as fast as it was required, and the company entered into agreements allowing their contractors on the Isthmus to buy their own plant, which became the property of the Canal Company on payment of 15 per cent. of commission to the contractors, who, induced by this high rate, purchased machinery in quantities largely in excess of the amount necessary for constructing a sea level canal, and very greatly beyond what is now required for the completion of the works with locks.

The climate is deadly. Contractors rush in to make the largest amount of money in the shortest possible time, and in some cases they made unfair claims, which were paid by the Canal Company as if it had been a bank of inexhaustible supply; the contractor rushing out again to enjoy the results of his labour and risk in a more healthful climate.

Among the dredges described as in use is the American Hercules type, which consists essentially of an endless chain with buckets, which carry the material to the top of a tower seventy-feet above the deck, from which point it is discharged through long pipes (which are braced and fastened to the tower) upon the bank of the canal. They cost from £20,000 to £24,000 each. There are from forty-five to fifty-five men aboard of them, who work day and night in three watches. The average amount of material excavated is about 100,000 cubic yards per month, and they consume about 10 tons of coal per day. The high tower and discharge pipe makes this type of machine self-contained and independent of the supply of clappets for taking away the material.

Scotch dredges, of the Clyde type, are also in use—their boilers are of 200 H.-P., consuming 6 tons of coal per 12 hours; and in ordinary work discharge from 2000 to 3000 cubic metres per 12 hours into clappets.

The French dredges are stated to be the principal machines employed along the canal; they are built in France, taken to pieces, and sent out and cost approximately £23,000 each at Colon. They give good results in stiff clay and rock work, and discharge from 200 to 250 cubic yards per hour into clappets alongside. They require, however, a greater number of skilled men to work them. In some cases, French dredges, by undermining the banks and causing them to fall into the stream, have been able to remove earth 30 feet above water level. The discharge of the material, which is broken up by being forced with water through gratings, is effected by a steam scow carrying a centrifugal pump, which

forces the water and disintegrated material through 600 feet of corrugated iron pipes to a height of 45 feet above water level, the machinery working at the rate of 1200 yards per day.

A system of hydraulic discharge is also in use, in which an iron barge alongside the dredge, carrying three horizontal pumping engines 20 inch dia. and 3 feet stroke, forces the disintegrated material received from the dredge through iron pipes, carried on pontoons, to the shore. In this case the material does not pass through valves or pumps of any kind, being simply forced along by streams of water, under high pressure, projected against it.

The Belgian dredge is described as similar to the French, costing somewhat less—£18,000 each ; but Scotch, French, and Belgian machines can only work during the day on account of the liability of their attendant clappets running aground on the way to the dumping places during the night, owing to unsafe pilotage.

Rock-drills of the Ingersoll type, of which a large consignment was sent out, were only employed a few days, there being an insufficient number of skilled workmen to instruct the natives in their use ; and French machine drills are said to have proved a cumbersome appliance. A submarine rock drill has been successfully employed. In the hull of a steam-boat, 50ft. by 20ft., is an open square, 20ft. by 15ft., and over this hole is an open frame with a fore and aft motion, supporting four drills which are actuated from the crank shaft by bevel gearing. A water tight telescope pipe is lowered from the drill frame and driven down into the bottom of the channel, and inside this pipe the drills work. Coral rock has been attacked in this manner, and, when disintegrated and broken up by blasting, is raised by the dredges. At the present time only churn drills from 6 to 15 feet long are in use, the general policy being, in the absence of intelligent workmen, to use simple appliances with which the ignorant labourers may accomplish satisfactory work when left to themselves. Where the rock has been porous and open, and the charges blow out through the strata, shafts a metre square and some ten metres in depth have been sunk, and from the foot of these, chambers two metres on either side ; these chambers and part of the shafts are filled with powder or dynamite, the top five metres of the shaft being tamped with solid cement. A number of these shafts are fired at once, shattering the mass, which is afterwards attacked with picks. In soft rocks this has been found the only successful means of working.

The paper goes on to describe the rails, locomotives, waggons, and cranes employed, and states of excavators, that various styles of the endless-chain-and-bucket kind are in use—both "down-digger" and "up-digger" types. The Osgood excavator, a type of machine in use in this country, is also employed. This digger is capable of excavating cuts up to 70 feet in width, and delivering the contents of its digger 29 feet above the rails. Generally, the excavators are capable of cutting out

from 1200 to 1800 cubic yards per day, and weigh from 30 to 36 tons each. During the rainy season, however, they give bad results, the "down-digger" kind, resting on the edge of the slope by its weight and the vibratory motion set up by its working, causes the slope to slip; while with the "up-digger" type the steep face of the work slips also, covering up the rails on which the machine moves, so that cranes and simple buckets have to be substituted, but these are not capable of putting more than 60 to 100 cubic metres, per day of 12 hours, into trucks; and it may be stated here that all rock cutting is dealt with in this primitive fashion.

In connection with one of the endless-chain-of-bucket excavators, a transporter is employed carrying the material 500 feet distant, and to an elevation of 50 feet. This is managed by causing the excavator to discharge on to a travelling band, 4½ feet wide, which carries the material to a spoil bank, and it is so arranged as to move along as the excavator advances.

For the formation of the canal the first estimate of the work was 46 million cubic metres to complete it to the sea level; this was increased later to 151 million cubic metres. Up to June, 1888, 49 million metres had been taken out at an average expense of 3·62 dollars per metre. It is estimated that to complete the canal with locks some 40 million metres are yet to be taken out, which will occupy three or four years' time.

Profiles of the canal, which were issued by the Canal Company, accompany the paper, and give an accurate idea of the work done and the work still to be accomplished in the formation, both to the lock level and the sea level. From the Colon end, the first ten miles in the low ground is practically complete, but out of the great Culebra Cut, which was to have been 354 feet deep to the bottom of the sea level canal, only 93 feet has been taken out, leaving a depth of 111 feet still to cut to the level of the upper locks; the slope adopted is 1½ to 1, but at this angle great difficulty is said to be experienced from landslips. In the Emperador Cut, the excavation still required to reach the lock level varies from a depth of 60 to 120 feet, and heavy deviations and dams have still to be made to control the rivers. The paper is severely critical of the way in which the work has been carried out, and sceptical of its ultimate success. It is well illustrated by numerous views of the machinery and works, which have been re-produced from photographs taken on the ground.

J. G.

Transactions of the AMERICAN SOCIETY OF CIVIL ENGINEERS.

HIGH WALLS OR DAMS TO RESIST THE PRESSURE OF WATER.

By JAMES B. FRANCIS. P. 147.

THE failures of great works are not without their uses. Rightly considered they are experiments to full scale working marking a limit which

may not be passed. The designer may be a genius, yet the failure of his work draws down upon him the ready censure of the common herd. But in speaking sternly of those responsible for the construction of the dam, the giving way of which resulted in the annihilation of Johnstown, men may not be accused of being wise after the event, because M. Krantz, Ingenieur des Ponts and Chaussees, in his "Study on Reservoir Walls," published many years ago, after recounting many disasters from the failure of high masonry and other dams, says:—"In view of such chances, the engineer must not be too bold, nor take upon himself before the public a responsibility which is powerless to repair such disasters. However little it may lean toward rashness, boldness in such cases may almost become a crime. In my opinion it is better not to build reservoir walls if we have not the necessary resources to build solidly than to build carelessly at the risk of frightful catastrophes."

Usually, in designing masonry dams, it has been the custom to consider the material rigid, and that the forces acting on it were the pressure of the water on its vertical face tending to overturn it about its outer toe, and the weight of the wall opposing that tendency. If the weight were too little, the dam might fail by overturning, or it might give way by sliding at the bottom or any higher point, or it might fail by crushing of the material.

The points Mr Francis attempts to make good are (1st) that if it is strong enough to resist overturning, it cannot fail by crushing; and (2nd) he shows that another element should be taken into account, viz., the upward pressure of water finding its way into the cement mortar under the base of the dam, and increasing the overturning movement.

He follows the usual practice by assuming, in order to get the necessary stability, that the resultant of water pressure and weight of material should intersect the base at a point from the perpendicular face equal to two-thirds of the base length, and demonstrates that for the triangular section of dam the breadth of the base should be from ·63 to ·66 of the height according as the specific gravity of the masonry is taken at 2·50 or 2·25; and on the assumption that there is an upward pressure on the base of the dam, equal to the head of water at the upstream face, and gradually diminishing towards the down stream toe, he shows that the breadth of base should vary from ·81 to ·89 of the height.

If the masonry were rigid, the maximum pressure, per square inch, when the dam is full is at the down stream toe; but at that point the masonry is weakest, and Mr Francis contends that the material there is compressed, and the strain transferred further into the interior, where the resistance to compression is much greater, chiefly on account of the lateral confinement of the stone increasing its supporting power. In this way the toe is relieved from dangerous pressure. He illustrates this transfer of pressure by reference to mines, where the pressure is shifted to the

sides of the drivages, but before this can take place there must be some yielding. The manner in which he makes good his point that the resistance to crushing is much greater in the interior of a mass, is very interesting. He points out that tests made on cubes of granite would lead to the conclusion that this strong rock would be crushed at a depth of four miles, which is not likely to be the case; and he shows that with a certain sandstone 1in. cubes were crushed by a pressure of 7000 lbs., four such cubes should therefore yield to 28,000 lbs.; but direct experiment on a piece of solid stone 1in. deep and 2in. square (equal in area to four 1in. cubes) proved that it carried 38,000 lbs., thus showing a much higher mean resistance per square inch.

As to upward pressure under the base of the dam, involving the question as to whether the pressure of the water can be communicated through the capillary channels in the mortar, Mr Francis made experiments with a pipe filled with Portland cement mortar, composed of one part of cement to two of sand, and 15¾ inches thick, and found that with a pressure of 77 lbs. applied on one side of it, the pressure transmitted to the other side varied from 40 to 73 lbs., thus showing that, under some circumstances, hydrostatic pressure can be transmitted through a certain thickness of cement mortar. J. G.

Transactions of the CANADIAN SOCIETY of CIVIL ENGINEERS. Vol. II.

COAL MINING IN NOVA SCOTIA.

By Mr E. GILPEN, Jun. Page 350.

THIS paper is by a Deputy Commissioner and Inspector of Mines. The coal outcrops in the sea cliffs of Cape Breton are visible for miles, and in the olden time the coal was freely stolen from them. Preventive officers were appointed, and of one it is related that, zealous in his duty, he set the exposed beds on fire, and so put an end to farther depredations. The first regular working was undertaken in 1720 for the supply of the fortress of Louisberg. Little was done, however, till 1827, when King George the Fourth, to relieve his brother, the Duke of York, from financial embarassments, granted to him for the term of sixty years all the mines and minerals in the Province, subject to certain rents and royalties for the purposes of the Provincial civil list. The Duke transferred his interest to the General Mining Association of London, who began to develop the coal resources. In 1858, certain arrangements were made, whereby this monopoly retained possession of 46 square miles of coal lands, and surrendered its rights to the Government of all coal and other minerals in the remainder of the Province. The Government grants licenses to search for twelve months over an area not exceeding five square miles, and out of this during the year the holder may select one

square mile, and in it secure a license to work for three years and if, during this period, effective mining operations are begun, he is entitled to a lease for eighty years.

The Cape Breton seams vary from 4ft. 9in. to 9ft. thick, mostly lying flat, and those of Pictou from 4 to 15ft.—the main seam is 38ft. thick—rising about 1 in 10; and the Cumberland seams run from 3½ft. to 11ft., and are as steep as 1 in 3. The main seam of the Pictou district has been worked with rooms 18ft. wide, separated by pillars or rances 8 to 10 yards broad. The first working is in the top of the seam, and is from 12 to 15 feet in height, leaving 18 inches of coal for a roof, and a second working of 15 to 20 feet in height was afterwards taken out in the pavement of the rooms already made in the top coal. Beams of 6-inch timber, securing the sides of the pillars, were placed horizontally at the level of the floor of the first working, and on these beams as soles, props were erected where the roof was bad. The working was high and dangerous, the rances ill calculated to support weight, and further weakened by the oblique direction of the cleat, and have mostly crushed. It is stated serious fires have occurred in the wastes, some of which have been only overcome by filling the workings with water.

Of late years the seams have beeen opened where possible by slopes from the surface, leaving a crop pillar of one hundred yards or so. In the steeper workings the coal is lowered to the levels by incline balances. In the higher seams the loss in working is given at 18 per cent. "in the bords and heads," and in taking out the pillars from 15 to 20 per cent. In a few collieries the extraction of pillars is systemically carried out, but in the flat lying seams of Cape Breton little stooping has been attempted, as great quantities of surface water are liable to be brought in at the shallow depths of the workings there. The seams are mostly free from gas except in the Pictou district, which is decidedly fiery, and where safety lamps are more or less used, and the employment of gunpowder in special cases prohibited.

At several of the Cape Breton mines the water has a strong acid reaction, and of course gets stronger when allowed to run over the small coal and rubbish in the rooms. Phosphor bronze, and other metals are in use for the pumps, and sometimes they are made of wood, the iron straps, clamps, and flanges being protected with layers of tarred flannel. Direct-acting steam pumps are mostly in vogue, and the water lifted is about three times the weight of mineral raised.

The paper gives several tables of details of pumps, pumping and winding engines, and of the number of men employed, and the output of the different collieries, the total production of the Province for the year 1887 being 1,670,838 tons of coal.

The royalties paid are about 9·7 cents per ton for round coal, passed over a ¾ inch screen, and 7·5 cents per ton for "run of mine," that is coal and dross.

J. G.

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EXTRACTS FROM REPORTS OF THE INSPECTORS OF MINES FOR 1888.

Mr MOORE, East Scotland District.

THE output of shale shows a large increase. This new industry is assuming large proportions in this district; it employs 4,464 men in mining alone. Its rise has been very rapid. In 1875 the output of shale was 377,108 tons; in 1880, 730,777 tons; and in 1888, 2,026,779 tons. The operations, with one exception, are in the hands of limited liability companies, whose capital is over two millions sterling, and perhaps 10,000 men are employed in all the departments. The geological position of the shale measures is that known as the "Calciferous Sandstone Series," which lies between the Carboniferous Limestone and the Old Red Sandstone. So far as at present known, it appears to be best developed in the counties of Linlithgow, Edinburgh, and Fife. Workable seams of shale have not yet been found in the same measures in the other counties in Scotland. The strata lie in comparatively small basins, dipping almost vertically at the outcrops and flattening out in the centre. For the most part, the mode of working the various seams has been to start at their outcrop, and drive a drift or mine in the seam, instead of sinking vertical shafts. The loaded tubs of shale are drawn up these mines by means of engines placed at the surface, and in some cases 600 tons a day are drawn up one drift. The mode of working is generally by stoop and room, and the shale is for the most part blasted with gunpowder. Where there is a "holing" of softer material, it is holed with picks; but in many cases the holing also is done by blasting. The seams give off fire damp, but, as a rule, are all worked with naked lamps.

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If an explosion on a large scale should unfortunately occur, I would recommend that men of the very highest standing in science should be at once summoned; and, whenever sufficient ventilation has been restored, should enter the mine to see the traces of the disaster, when as little disturbance of them as possible had taken place. Gentlemen like some of those who acted on the Royal Commission, though not practical men, are men of science with trained minds, and are most likely to throw some new light upon the subject. The inquiry by the Royal Commission was in the right direction, but experiments in the laboratory give but a faint idea of the desolation caused by a large explosion. The comparatively new theory that the combustion of dust in dry mines forms the chief factor in feeding the flame in an explosion accounts to my mind for much of the loss of life in many large explosions, but inspectors want the assistance of more scientific minds to strengthen their conclusions on this point, and the data are best collected at actual explosions. One

thing is abundantly clear, that unless the fire damp or the dust came in contact with the flame there would be no explosion ; and there are only two causes of flame in mines (1) the miners' lights, and (2) that caused by the explosions of gunpowder. With regard to miners' lights, it seems perfectly clear to me that explosions would be greatly reduced if, whenever fire-damp had been met with in any mine, safety lamps only were used. There is a prevalent idea that where safety lamps are used, other accidents, such as falls of roof, are likely to be more frequent in consequence of the inferior light which these lamps give, but statistics and practice show that the idea is contrary to fact. I have always looked forward for a better and safer light to the invention of an incandescent electric lamp which could be suplied as cheaply and used as handily as the ordinary naked light. With a lamp of this kind there would be no inducement to use any other light, and the difficulty—and there is a difficulty—of getting miners to use safety-lamps would cease. Such a lamp has not yet been got, although some good attempts have been made, and ultimately, I believe, they will be successful. With the use of the incandescent lamp, so far as miners' lights are concerned, explosions would cease.

With regard to the flame produced by the explosion of gunpowder, it is all very well to say that gunpowder is used without accident in our mines from day to day, and up to within an hour or less of the occurrence of an explosion. The fact remains, however, that many large explosions have been traced to shot-firing. I look upon the conditions to be observed in the new Act as to the use of explosives as of little use. Accidents will happen because of the neglect of these precautions, or because they are insufficient, and I feel satisfied that so long as we continue to use gunpowder under those conditions, the risk from explosion will not be lessened. The old Act, by which the men in the district were to be out of it when a shot was fired in a fiery mine, was preferable to the system authorised by the new general rules.

I have always been of opinion that the minimum number of accidents from falls of roof and sides will never be reached until the care of the roof and sides of the miners' working places is put upon the owners and officials, with no power to delegate it to the miner. By the present practice, the miner takes care of the roof and sides of his own working place, and it is assumed that he is able to rely upon his judgment to detect when they are insecure and require props and other supports ; but every accident that occurs shows that it is unsafe for anyone to trust to appearances as to the security of the roof.

It is clear to me that, in addition to props being set up where they are thought necessary, they should be set up at regular intervals as dictated by the manager, whether the roof seems to require it or not.

I think this will not be done unless by the owner appointing a trained staff of men to do it ; and until this is done I do not look for any great

improvement. It is only fair to say that the improvement which has been made during late years has been due to the better discipline exercised by the managers.

In miscellaneous accidents underground, there was an increase in accidents from trams and tubs. This is a matter which managers should look to; it is mainly in their hands. An attempt was made by Mr Ronaldson and myself to get a special rule, prohibiting drawers from going in front of their tubs while in motion down hill. The owners objected to this rule, and it was withdrawn. I hope it will not be lost sight of, as it is evidently needed.

As stated in my former reports, there has been a gradual improvement in the management in mines. The science of mining, like everything else, has been advancing, and there has been steady progress in the uniformity of management of mines. This is very well seen in the various Mines Acts; thus in the Act of 1857 there were only 7 general rules which were thought to be applicable to all the mines in the kingdom; in the Act of 1872 these were increased to 31; and in 1887, such was the uniformity that there were 50 general rules that the Legislature, with the consent of representatives both of owners and workmen, found could be observed in all the mines in the kingdom. Both owners and managers are pretty well agreed that most of the requirements of the Mines Act are necessary for economy as well as safety. The general result is that the arrangements and discipline have improved, and it is to this improvement that the saving of life and immunity from accident are largely due.

With regard to the miners and other workmen, they are now better educated, and ought, therefore, to be more able to devise the best means to ensure their own safety, and also to assist the owners and managers as far as they can in carrying out the general safety of the mines; but they do not give this the attention it deserves, and I have again to call attention to the want of interest which the miners take in the 38th general rule, by which they can appoint some of their number to examine the mine and see what the management is doing to promote their safety and comfort. Such examinations are very seldom made, and it is a great pity that it should be so.

Government inspection can only claim to affect the safety of mines in an indirect manner. This will be at once seen when it is considered that it is estimated that there are 30,000 persons in the mines of the kingdom, whose sole duty it is to look after the discipline and safety of the other workmen.

It seems to me that the practical view which the owners should take of the Mines Act is that the miners do not either individually or collectively take care of themselves, and that it falls upon them to do so. This they can do (1) by having the best machinery and arrangements; (2) by having good managers and officials; (3) by having strict discipline in carrying out the regulations.

I have always endeavoured to place these views before the owners and managers in the course of my examinations, and also to make known to them any improvement which had been adapted in colliery work, with the object of assisting its introduction in my district.

It is all very well saying that the miner ought to take care of himself and comply with the rules laid down, and that it is not right to allow him to think that he has to be taken care of, and no doubt there is much truth in the remark; but the fact is well known to all persons versed in mining that he does not take sufficient care of himself, and unless the management interferes the greatest safety will not be reached.

It is quite possible that the Employers' Liability Act, which has been very fully taken advantage of in the district, has influenced owners against taking up any responsibility whereby their liabilities for accidents would be increased, and in this view it would be very desirable that the Bill proposed by Mr Baird should be passed. This Bill proposes to pay for all mining accidents from a fund raised by a general contribution from the lessors, lessees, and miners.

Payment of men when off work owing to injuries is not altogether new. In the mines in the counties of Northumberland and Durham a custom has existed from time immemorial of the owners paying to any one hurt in the mines an allowance of 5s per week, known as "smart money,' while he is unable to work, and it does a great deal of good.

I may mention a few of the improvements introduced into this district, which, although not called for by the Mines Act, have had a considerable effect in enabling a greater number of tons of coal to be raised per person employed, and of course adding to the safety of mines.

Within the last 20 years, the ventilation has been much improved by the introduction of fans, which are gradually superseding furnaces, and there are now 188 of them in operation.

Coal-cutting machines are slowly gaining ground. They are used for holing only, and an average machine will hole 3 ft. 6 ins. for 180 yards in a shift. The machines are driven by compressed air, and as they are generally working during the night, and the miners take down and fill the coal during the day, the rate of progress of the faces is more than doubled. They have only been used in longwall workings and in seams from 2 ft. to 4 ft. in height. It was thought at one time that the distance between the roadways might be increased so as to save brushing, but of late the usual width of 14 yards has been adopted. Taking everything into account, there is not much saving in the cost per ton for hewing with wages at ordinary rates, for the persons employed at the machines, at the steam engines, and the cost and upkeep of pipes is considerable, but there are fewer men employed at the face and fewer persons required for a given output. They have been in operation for many years at Penston Collieries, at Gartness Colliery, at Springbank Colliery, at Whitehill Colliery, at Bothwell Park Collieries, and also at Alloa Colliery, and are long past the experimental stage.

At present a heading machine for driving narrow drifts is being tried at Hamilton Palace Colliery.

Arrangements for cleaning coal have made great progress. They are generally of one type, an endless band of iron plates about 4 ft. in width worked by a steam engine. The coals are run on to this band, and the stones are picked out by men and boys as the band moves onwards and deposits the coals into the waggons. The first person to adopt this was Mr Thomas Whitelaw, of Dalziel Colliery, and they are now becoming very general.

Coal washing and separating machines are now much in use for the cleaning and sub-division of small coal into various marketable sizes.

The two last improvements have rather added to the number of persons employed, but on the whole fewer persons are employed in colliery operations for a given quantity of coal raised.

Although the improved mode of stoop and room working, whereby the pillars were systematically worked away, was introduced into Scotland by the late Mr Matthias Dunn, at Prestongrange, in 1831, it was first introduced into Lanarkshire, so far as I can make out, by the late Mr William M'Creath, mining engineer. Previous to the last 25 years, where the stoop and room method of working coal was adopted, about two-thirds of the coal was worked out in the first working. and the pillars left were so small that but a very small proportion of them, if any, was ever recovered, and then at very great risk. Mr M'Creath stipulated first in the Hamilton leases that where the coal was worked by the stoop and room method, the pillars were in no case to contain less than 400 square yards, irrespective of depth of cover, so that about 70 to 75 per cent. was left in pillars, which could be systematically and safely worked out. The advantage of the system has become so apparent that where there was no restriction as to size of pillars it has been adopted, and is now almost universal. Generally the pillars have been made larger than 400 square yards, so that in most cases the rooms in the first working are only 9 ft. wide, and the pillars contain 75 to 80 per cent. of the coal. While working out these pillars a very liberal supply of props is used, not so much for preventing accidents as for carrying the roof until the lift of coal is taken off. When the lift of coal is worked off, the timber is withdrawn by trained men, and is used in the next lift. The result is that the number of accidents or of lives lost is not greater now in stooping than in the ordinary workings, and about 95 per cent. of the whole of the coal is got out. Indeed, in this way, the loss of life by falls is actually less by stoop and room than by the longwall method of working.

The mode of haulage by endless ropes on level roads has been greatly on the increase in this district. It is now very general in the Hamilton district, and effects a great saving in the number of men and horses employed in conveying coals from the faces to the shafts.

The single cylinder engine which was used for winding, and which often

by gearing did the double duty of pumping and winding, is rapidly passing away, and is being replaced by improved double cylinder engines working on the first motion. Engines for raising water have also been much improved, and the steam engines and machinery for winding and pumping in the district are second to none in the kingdom. Much credit is due to Dr David Landale, and to Mr Andrew Barclay, engineer, Kilmarnock, for introducing these improvements.

MR RONALDSON, West Scotland District.

THERE were 24 non-fatal explosions, resulting in the injury of 35 persons, as compared with 20 explosions and 25 persons injured during the year 1887. Of these, three happened to firemen while making their inspection, previous to the descent of the workmen, with an open light instead of a safety lamp, as required by the general and special rules. It is difficult to understand why men who are supposed to be gifted with at least ordinary intelligence, will risk their lives in this manner. The conduct of these men illustrates the fact, which is frequently brought out in other ways, that in mines where firedamp is seldom found, officials and workmen alike are apt to act as if it were never to be found. In these comparatively non-fiery mines where naked lights are in use, no one should ever take it for granted that firedamp is at any time absent, but should take the same precautions that are so necessary in mines where firedamp is freely given off.

As I anticipated a year ago, the new special rules now in force contain no more stringent regulations regarding the keeping of roofs and sides secure than did those in force under the Coal Mines Regulation Act of 1872. It is often the most experienced miner that gets injured by a fall, and that shortly after his working place has been visited and examined by the no less experienced official. The fact that so many of these accidents do occur proves that a life-long experience in itself cannot always guard against the unseen causes which bring them about, and that it is as necessary to take the same precautions when the roofs and sides of the working places appear to be good as when they seem to be insecure.

Explosions of gunpowder caused 10 non-fatal accidents, which is a greater number than that for the previous year. So far, it does not seem that the new rule which requires explosives to be taken into the mine in cartridges has brought about any increased safety. I have, however, found more difficulty in getting this rule complied with than any other new rule introduced by the recent Act. Not only have the workmen strong objections to using powder in cartridges, but in many instances the owners, managers, and under officials alike have not taken the necessary steps to see the requirements of the statute observed. Many

workmen are in the habit of making up their cartridges in their own homes, contrary to the Explosives Act, and to the danger of their families, and some of them as an excuse plead that they cannot get powder in cartridges to buy. They object to cartridges on the ground that they do not know what size they may require, but if various sizes were taken into the mine it would seldom happen that a miner would not have beside him a cartridge of the exact size he wanted. I understand that the manufacturers can supply cartridges of any size ready for use, and where not obtained in this way, I would recommend the owners to follow the example set by some of making up the cartridges of the various sizes required by their miners in a magazine set apart for the purpose.

I am not aware that at any mine advantage has been taken by the workmen of the power conferred upon them by General Rule 38 to inspect the mine either through two of their own number or other two practical miners. Apparently they do not approve of inspection of this kind, and although much can be said in its favour, from another point of view there are objections to it.

MR WILLIS, Newcastle District.

NOTWITHSTANDING very careful and repeated examinations and timberings by officials, much must depend on the hewer himself in securing his own safety. Fresh exposure of roof by the extraction of the coal, and consequent new sources of danger, is a continuous process and requires most careful watching.

Mr BELL, Durham District.

IT will be observed from the summaries that there have been no accidents from explosions of gas in the district during the year. This result is no doubt due to greater care in blasting, to the use of flameless explosives, more attention to keeping down the dust by watering and clearing it out of the main haulage roads, and to some extent to the discontinuance of blasting altogether.

The deaths from falls in the mine are higher this year than usual, being four more than the average number during the last five years. They compare favourably, however, with other districts. The loss is one life for every 557,310 tons raised in the Coal Mines, and one for every 674,490 tons raised in the Ironstone Mines of Cleveland, being an average of one life lost, by falls in the mine, for every 557,307 tons of mineral raised; the average loss of life from the same cause throughout the whole kingdom being one for every 387,813 tons raised. Several of these accidents were caused by the carelessness of the miners themselves in neglecting to set timber when ordered to do so, and in two instances by

the removal of props after they had been set by the deputy. Several fatal and numerous accidents causing serious personal injury take place from the persistent negligence and careless manner in which the miners sprag, or neglect altogether to sprag, the coal while holing or undercutting, and although there are stringent special rules to enforce the propping of the place, or spragging the jud by the workmen during the absence of the deputy, they are very often quite disregarded.

The increase of accidents that has taken place in late years on engine and incline planes, by machinery and trams and tubs, may be in a great measure accounted for by the greater amount of roadways now in use, by the great amount of machinery and mechanical appliances introduced into our mines so as to facilitate and economise the cost of the output of mineral, and the larger number of people now employed in this class of work.

I have received 16 complaints, chiefly anonymous, from the workmen at the Coal Mines, and one from the Cleveland Ironstone Mines. Only one copy of the workmen's report as to the existence or apprehended existence of danger, made in their monthly inspection under the 38th general rule, has been forwarded to me. They all had immediate attention.

Mr WARDELL, Yorkshire and Lincolnshire District.

THE mortality under the column "falls in mine" is, although short of the number in 1887, when it amounted to 74, still terribly heavy, exhibiting, as it does, a total of 53 deaths as produced by 52 separate accidents. This class of accident therefore contributed about 60 per cent. of the total mortality. In the previous year the per-centage was 67. Constant supervision by managers and those in charge, coupled with a thorough system of discipline on the part of workmen, are amongst the essential precautions to be adopted for minimising the death rate from this class of accident.

The usefulness and beneficial effects of the St. John Ambulance Association become more and more apparent as its numbers increase and centres and branches are opened out. As I have before stated, I have myself personally witnessed and heard of cases where the invaluable knowledge of first aid has in all human probability been the means of saving life, and certainly minimised pain and suffering. Ambulance appliances in the form of stretchers, with splints and bandages, are now required, by a general rule of the Act, to be kept at the mine ready for immediate use. At many collieries this was the custom even before the law required it. And in every case, where practicable, these appliances should also be in readiness below ground. At some of the larger collieries in this district they are ready for use, not only at the bottom of the shaft, but in the various divisions and districts of the mine.

The law now requires that the materials shall be at hand, but unless men are taught what to do, and how to use the appliances, there would be comparatively small advantage. And it is this knowledge that the St. John Ambulance Association is spreading and teaching throughout the country.

An appreciation of what now forms the 38th general rule, is, I think, becoming more strongly felt, and the benefits arising out of an inspection from time to time of a mine by two of the workmen, or any two practical working miners, are calling forth an extended application of the powers conferred under this rule. I am of opinion the rule is an admirable one, and should like to see a still further recognition of the salutary effects consequent on its observance.

The 39th general rule is one also upon which too great a stress cannot be laid. It provides for a period of two years' experience of coal or ironstone working under skilled supervision as essential and imperative before any one can work alone in a mine as a coal or ironstone getter. It is this want of experience, and complete ignorance of even ordinary matters pertaining to such work, which has not only caused accident and death to these inexperienced men themselves, but has probably involved the deaths of others who, but for them, might have been alive to-day. Gradually, I feel sure, the efficacy of this rule will make itself very evident.

The loss of life from falls of roof and coal seems to claim special attention, for by far the largest proportion of deaths results from this cause, and this not in the single year under report only, but year by year. It seems to me that timber should be set even where there is an uncertainty as to its need, that all the rules relating to this question of timbering should be scrupulously enforced and faithfully carried out, that a plentiful supply of timber of the various sizes required should be always at hand, and that too careful and too frequent an examination of roof and sides cannot be made, and an examination too for the purpose of detecting any unsafe place either by reason of "slips" or other causes, and not *only* (as is sometimes thought to be the object) to discover *gas*.

Closer attention to these matters, I am of opinion, would materially effect a reduction in this prolific source of mortality.

Mr DICKINSON, Manchester District.

SAFETY lamps having now to be constructed so that they may be safely carried against the air current ordinarily prevailing, even if it were explosive, many Davy lamps have had to be dispensed with or the construction altered so as to suit the requirement.

The Marsaut safety-lamp, which in 1883 was first introduced for working

with in the Altham Colliery in this district, is now generally used in a large number of the collieries, many thousands of such lamps being in use. The Mueseler safety-lamp is also used in some collieries.

Opinions vary with respect to whether oil or spirit is best. Some who have tried both for many years prefer oil for the drawers or waggoners on account of the light not being so readily extinguished, but spirit for the colliers, as the lamp burns during a shift without trimming; others, however, with lamps made on the newest principles, hold that oil is best.

For testing as a fireman's lamp, the protected Davy is still commonly used, but at Altham the Marsaut with spirit lamp is now preferred, as it shows the presence of a smaller percentage of gas than with oil.

The further restrictions under the new Coal Mines Act have lessened blasting to some extent, and high explosives have displaced powder in some firedamp mines, but in other mines powder is still largely used. In addition to the Settle Gelatine Water Cartridge, other explosives such as "Roburite" and "Bellite" are being tried. Most of them appear to afford very considerable, if not entire, protection against ignition of firedamp, but it is found that occasionally when a shot blows the stemming, or the cartridge or the detonator is imperfect, either the cartridge ignites without exploding, or sparks are given off which might ignite firedamp, and that, therefore, to be quite safe, precautions the same as with powder should be observed.

It also appears that some of the new explosives require detonators so powerful as to require more than usual care in the using; and that the composition of the explosive is poisonous if handled, and that, notwithstanding statements to the contrary, the fumes after the explosion are injurious to health, and should be removed by ventilation before persons re-enter.

The precautions enjoined by the Act as to shot-firing in main haulage roads have by the special rules in this district been made to apply also to main return airways.

Machines for cutting minerals, instead of by hand-picks, are used in a few instances.

The Walker machines for holing in rock-salt are working successfully in three of the rock-salt mines at Northwich.

The Stanley coal heading machine is being tried in two of the Lancashire collieries, and it appears to work well when the coal is hard enough, and when sufficient pressure of air is kept up at the engine. The first cutting is made in the form of a disc, and then the core is removed, and the circle formed afterwards into any other shape that may be required.

Mr HALL, Liverpool District.

THE aggregate number of fatalities from falls of roof and side increases year by year. This is true of the kingdom as a whole, and it is more especially true of West Lancashire and North Wales, and I do not think there can be any doubt, as pointed out in many previous reports, that this result is due to the fact that the miners take largely upon themselves the responsibility of timbering the working places in mines. I am of opinion that neither the Act of Parliament of 1872, nor the present Act, has dealt adequately with this subject, and the position the workmen have taken up in the matter puts them out of Court so far as the "Employers' Liability Act" is concerned, because they would inevitably be considered contributing parties to any accidents from insecure timbering in a working place.

The remedy for this state of things seems to lie in one or other of the following directions. Either the principal part of the timbering should be taken out of the hands of the miners and performed by skilled officials, as is the case in Durham and Northumberland, in which districts fatalities of the description referred to are not nearly so frequent, or if the miners are to continue to do the work of timbering, then they should be compelled to do it systematically, that is, in accordance with a well-considered rule laid down by the manager, specifying the extreme distance between proper supports for the roof. If the latter plans were adopted, the miners would then act under orders, and would thus be compelled to timber up to a certain standard of security, whether they liked it or not, or whether it interfered with the filling and sending up of an extra tub of coal or not, and more responsibility would rest upon the officials, a responsibility which under the present practice has all but disappeared, leaving the workman to shift for himself, so far as the most dangerous part of his occupation is concerned.

I have personally watched many of the experiments with "Roburite," and have taken every opportunity to make inquiries as to its behaviour in the mines where it has been for some time in constant use day by day, and I cannot find that the objections which have been urged are of such a serious nature as to discredit it, or prove it to be actually dangerous; indeed, I am satisfied we have in this explosive a most excellent substitute for gunpowder, and one that promises to give much greater security.

The result of careful watching of this new explosive seems to teach that noxious fumes to a very limited extent are given off, more especially when the cartridge has been allowed to get damp before use, but any injury to health can be avoided by giving the fumes a few minutes to clear away before again entering the working after a shot, and by keeping up a good ventilation.

The unshielded Davy and Clanny lamps have almost entirely disappeared,

and have been replaced in this district by the Marsaut, Mueseler, and Park Lane lamps for the general body of the workmen, the firemen and officials generally carrying a shielded Davy. The lamp stations are now confined to the fresh-air roads, but in many instances these stations are far too numerous and situated too near the face of the workings. A leaden rivet with a letter or figure stamped upon it is now largely used to secure and lock the lamps in place of the Lancashire padlock and the old North Country screw. The latter was a most insecure fastening, and ought to have been discarded long ago.

The electric light has not made as much progress as it promised to do a year or two ago, and in no instance here is it in use at the face of the working; one or two firms use it for shaft work and sinking, to which purpose it is excellently adapted.

DR. FOSTER, North Wales, &c., District.

In my last report I referred to the success which had attended the working for gold at Gwynfynydd, or Morgan Mine, during the first three months of 1888. The total output for the year was 3,844 tons of quartz, which yielded 8,745 ozs. of gold, worth about £30,000. This result is very gratifying, and has naturally led to active prospecting for gold in the Principality, and not only in Merionethshire, but also in Carnarvonshire, Denbighshire, and Flintshire. In the course of the present year sufficient data will have been obtained for deciding how far Wales is likely to be a gold-producing country.

Two years ago I called attention to the crowded, dirty, and insanitary barracks at Rhosydd Slate Mine. Thanks to the exertions of the Medical Officer of Health some improvement has been made; but the dwellings of the men are still far from affording the degree of comfort to which, in my opinion, a respectable working man is entitled.

During a short stay on the Continent last summer I renewed my acquaintance with the famous lead mines in Mechernich, in Rhenish Prussia, and passing over many objects of interest above ground and below ground, I will here allude only to the barracks. These provide accommodation for about 400 men, some of whom are married, and go home from Saturday till Monday, whilst others are unmarried and have no home within reach. The workmen are perfectly free to do exactly as they please as regards living in the barracks or not; but, if they do live there, they must conform to the regulations.

The cost of lodging is 9d per week; for this a man gets a comfortable bed with a spring mattress and clean sheets and blankets. The beds I saw were such as I would sleep in without hesitation; I wish I could say the same for all the beds in the barracks of my district. The space allowed in the bedrooms is about 400 cubic feet per man, and in winter they are kept warm by hot air.

The cleanliness of the barracks was most striking, and this is partly due to the rule that the men on coming back from the mine must at once change their clothes and carry their underground suits to special outside premises, where each man has a locked cupboard. If wet, the clothes are dried for him; but this is not as a rule necessary, for the workings are quite as dry as an ordinary Welsh slate mine.

The men can be supplied with their meals at stated hours in the dining hall at low prices, and boiling water for making coffee is always ready for them gratis. The dining hall has a tiled floor, and the tables are scrubbed till they are exquisitely clean.

The sanitary conveniences are ample and well kept, and the men can have shower baths free of cost.

The mental comforts are not neglected; there is a reading room with newspapers, which is open after working hours, and a library from which the men can borrow books.

In fine, when I compare the comfort, cleanliness, and order of the German barracks, with the discomfort, dirt, and disorder of some of those in Wales, I do not feel proud of my fellow countrymen. On their behalf it is right to say that the Welsh miner or quarryman is paying much less for his quarters than the Mechernich workman, viz., only 1½d or 3d per week, and that many a man is glad to put up with discomfort if he can thereby save money and have a bigger balance to take home to his family. However, I am decidedly of opinion that if mining companies provide barracks at all, they should make and enforce regulations to ensure cleanliness and order.

Sheer ignorance is sometimes the cause of the evils which I should like to see remedied. Only a few months ago I came across some barracks in course of construction, and the well-educated manager of the mine, who, I am sure, had no wish to injure his men, had actually prepared bunks for 21 men in a room without a window or chimney, and containing only 2,200 cubic feet of space, *i.e.*, about one-third of the smallest amount which sanitarians would consider requisite. If managers will do such things as this above ground it is not likely that they will be very particular about ventilation below ground; nor can we wonder at the men being indifferent and careless.

Mr STOKES, Midland District.

I HAVE during the year received many complaints, both anonymous and signed, from workmen employed in mines in my district. The whole of them have received early attention, and the matters complained of investigated. I find that although workmen seldom avail themselves of general rule 38, which gives them power to appoint two of their number, or any two persons being practical working miners, to inspect

the mine on their behalf, yet they frequently forward complaints to the Inspector of Mines, with a request for investigation. Under no conditions are such communications made public, and so far as possible I personally attend to workmen's complaints sent to me for investigation.

I am pleased to say that I have no death to record from explosion of fire damp in this district during the year 1888. There have been a few non-fatal explosions, but most of them are of a slight character, and principally due to carelessness or inattention to the rules of the mine.

In my opinion this satisfactory record is due partly to the strict discipline and care which both managers and officials are now endeavouring to enforce, and partly to the increased use of safety lamps. I have always advised that, in a mine where gas is occasionally found, the driving of headings and work in clearing of falls or restoring ventilation should be done with safety lamps, and I frequently call the attention of managers and officials to general rule 8 (*a*), which provides that "No lamp or light, other than a locked safety lamp, shall be allowed or "used in any place in a mine in which there is likely to be any such "quantity of inflammable gas as to render the use of naked lights "dangerous."

The safety lamps principally used throughout this district are the bonnetted Clanny and Marsaut, which, with a flat wick and good oil, give a very fair light.

It is to be regretted that the number of deaths from falls of roof and sides are equal to 62 per cent. of the total number of deaths from all causes during the year. The high death rate from falls is not confined to this district, neither is it confined to any particular district nor mode of timbering, whether done by the workmen or officials, as the following table will more clearly indicate.

PERSONS EMPLOYED UNDERGROUND AND TONS RAISED PER DEATH FROM FALLS OF ROOF AND SIDES.

Falls of Roof and Sides.	Inspection District.												Great Britain.
	East Scotland.	West Scotland.	Newcastle.	Durham.	Yorkshire.	Manchester.	Liverpool.	Midland.	North Stafford.	South Stafford.	South-western.	South Wales.	
Persons employed underground, per death	962	1,126	1,503	1,067	1,044	953	699	1,197	788	616	1,069	656	932
Tons of mineral raised per life lost	448,024	452,768	628,358	577,253	395,405	362,974	267,292	478,992	361,731	372,755	343,813	229,102	388,638

In the above table I have calculated the death rate upon the persons employed *underground* only, because the persons employed above ground can in no way be affected by falls of roof and sides in the mine. A high death rate from falls has been recorded for many years, and appears to have been carefully provided for by the new Mines Act, for whereas there was one general rule in the Act of 1872 for the securing of roof and sides, there are two rules (Nos. 21 and 22) in the Act of 1887, the latter providing for suitable timber in the mine convenient to the workmen. I trust these rules, together with the provisions for timbering made by the special rules, will, if strictly carried out, reduce the loss of life from falls in the mine.

In this district it is the duty of the stallmen to build efficient packs and set a sufficient quantity of props, bars, or timber for safely supporting the roof and sides in their working place, also they must remove and renew the same when necessary, and it is the duty of the officials of the mine to see such rule carried out, and that a supply of suitable timber is distributed throughout the mine convenient to the workmen.

Stallmen or persons in charge of working places should be experienced colliers, accustomed to the timbering of roof and sides, who will keep a constant watch for any change or peculiarity which may appear in the overlying strata, whose experienced ear when sounding the roof would detect a dangerous piece of ground, and whose eye would be quick to see a natural slip or smooth parting exposed to view by the falling of the coal.

Difficulty and danger frequently arise suddenly in a working place, hence it is necessary that the persons in charge should be men of experience who will not hesitate to withdraw their men in case of danger, or use sufficient timber for safely securing the roof and sides of their working place.

It is equally important that the officials of the mine should give careful and intelligent attention to the timbering of the roof and sides of the working places and roadways. When passing through the mine during the working shift they should learn to foresee danger and not wait until a roof becomes dangerous before taking steps to secure the same. The officials should remember that not only have they to see that suitable timber be provided in a place convenient to the workmen, but it is their duty to see that the roof and sides of every travelling road and working place be made secure.

If the fatalities from falls are to be reduced it must be by the joint co-operation of both officials and workmen, a strict carrying out of the Act and the Special Rules, an unlimited supply of suitable timber convenient to the workmen, and a willingness to anticipate danger by fixing sufficient to safely secure both roof and sides of the working places and roadways of the mine.

The new rule inserted in the Mines Act, 1887, requiring ambulance or stretchers with splints and bandages at the mine, is, I believe, strictly

complied with at all coal mines in my district. Not only have ambulances or stretchers been provided at the mine, but in some cases stretchers are kept both above and below ground, and in a few cases a stretcher is kept in each district in the mine.

In this district there are 2,327 mine officials and workmen who are qualified to render first aid to the injured, and who hold ambulance certificates of qualification. These persons are not only competent to stop hemorrhage, but to improvise bandages and splints and direct the removal of the injured person with the least possible amount of suffering. In some cases the officials of the mine have bandages and splints at fixed points in the mine, but some of the best cases of first aid have been rendered by the use of a stone and a piece of the injured man's shirt or dinner bag.

There are now 597 mine officials and workmen in this district attending ambulance classes for instruction in rendering first aid to the injured.

In my opinion it is advisable that every mine official should hold an ambulance certificate. The stopping of bleeding or bandaging up of a broken limb so that simple fractures may not become compound fractures is, I think, more important than the placing of stretchers all over the mine.

MR WYNNE, North Staffordshire District.

I NOW come to the question of "blasting in fiery mines," and I am pleased to say that as "continual dropping wears away a stone," so, by my continual insistance on this topic, I have at last forced my opinions on this method of getting coals on to the minds of my colleagues and of the mining public generally, and have secured by the Mines Regulation Act of 1887 its practical abolition.

For many years at the annual meetings of the inspectors of mines I brought this subject forward, and generally had to fight the question single-handed; but, after more than 30 years' hard fighting, I now have my reward in finding that my often-expressed opinions are now the accepted opinions of those who formerly laughed me to scorn. For facts are stubborn things, and so many awful explosions have been so clearly proved to have been caused by the use of gunpowder (as no less than 78 explosions out of 96 which I have investigated have been clearly traced to this cause), that the fact is nowalmost universally acknowledged that if blasting with gunpowder is permitted in fiery or dusty mines explosions are sure to be the result.

I am happy to say that once again I can congratulate the managers of my district on the fact that there has not been one single life lost during the year from explosions of firedamp, which, considering that North Staffordshire is about the most dangerous district in the country,

speaks volumes for the care and skill of all concerned, and bears out what I have been constantly pressing on all concerned, that the abolition of blasting in fiery mines means practically the abolition of explosions in these mines.

The number of deaths from this cause is 22, or seven more than in 1887, when the number was 15. I fear this increase is in a measure due to the fact that the daily control and supervision of the mine by the responsible manager is to a great extent withdrawn, and the propping of the mine, and the discretion as to the general use of timber, is now left in many cases to men who have hitherto been acting under specific directions. For when, in investigating this class of accidents, I have put the question as to when the manager last visited the place where the accident occurred, in nearly every case I have received the same answer, "We now leave that to the under-manager;" and these men not having previously full control over the workmen, have not as yet that sense of responsibility for the safety of their men that probably further experience will give them.

And I must press most particularly on these men, what I cannot too often repeat, that if accidents from falls are to be decreased, and not allowed to increase, they must before all things insist that, before the loader is allowed to commence to load up the fallen coals, the roof shall be temporarily propped, and any overhanging coals pulled down or otherwise made secure.

MR MARTIN, South Western District.

In this district the qualifications of surveyor or draughtsman are too often expected to be combined with those of certificated manager, and the results in some cases are lamentable. A suitable manager may or may not be a first-rate surveyor, or may not be one at all, and, on the other hand, a good surveyor, although holding a certificate, may not be a desirable or competent manager. The importance of plans has, in many cases, not been recognised, and has not received that attention which the subject deserves and should have. This is, in a measure, due to the fact that efficient plans do not show a visible or tangible monetary profit to either lessor or lessee, as royalties are paid on tonnage, instead of acreage as in Lancashire. This system I look upon as fraught with much national as well as private loss, inasmuch as the parties working a mine have no interest in working more coal from a certain area than they can get with the greatest convenience and profit, and the lessor has no efficient check upon the waste in working.

I have noticed in Lancashire, South Wales, and this district that in many mines, where the danger from falls is greatest, but where the rules

as to propping, spragging, &c. are stringently and consistently enforced (to a degree which some persons may consider harsh), the accidents are considerably less than in other mines where there is much less danger, but where the rules are not so thoroughly complied with. In the former case the men take care to have their places secured in such manner that the officials cannot find fault, knowing that they would forthwith be reported and punished, while in the latter case they wait for the official to order them to set timber, knowing that no punishment will follow for not having done it before.

Mr ROBSON, South Wales District.

WITH regard to non-fatal accidents, it will be seen that about half the total number was caused by falls of roof and sides, the actual proportion being 49 per cent. The next largest source of accident was that of "trams," which caused fully 25 per cent. of the total number.

While in many cases the injuries were slight, there was a large proportion where the parties were seriously injured, and probably a few were incapacitated for following their own or almost any occupation. Besides the suffering involved in such a large nnmber of accidents, the loss in wages is considerable. Estimating the average number of working days which the sufferers lost at sixty, and taking a day's wage at four shillings, the loss in wages during the past year would amount to £7080.

The investigations into the fatal and non-fatal accidents show that they generally occur while the sufferers are continuing to work under conditions of assumed safety, and that this assumption of safety is shared in to a large extent by those in authority, and especially by the "competent persons" appointed by the owners to make the inspections under the Act. Not only is this so, but accidents recur again and again under almost precisely similar circumstances, and this remark applies to accidents of every description.

The prohibition of naked lights under the eighth general rule cannot be enforced by an inspector unless he can prove that there is likely to be such a quantity of inflammable gas as to render the use of naked lights dangerous. Now, similar conditions exist in mines worked with naked lights as in those where only safety-lamps are used; the ventilation is conducted on the same principle, and is equally liable to temporary derangement whereby gas may accumulate. The small explosions which occur are, in my opinion, sufficient proof of the likelihood of gas being met with. Then, as to the "dangerous quantity," it seems to me that where the system has failed, and an explosion, resulting in serious personal injury or loss of life, occurs, this also is proof of the danger, and that only safety lamps should be used. This

view of the matter has not, however, been upheld in cases of prosecution in other districts, and I have not, as yet, thought it advisable to recommend proceedings under the eighth general rule. I am confident that safety lamps will become more and more into use, as a precautionary measure, which, of course, is their only legitimate purpose. I believe that the number at present in use exceeds that at any former period.

There are more ventilating fans now than formerly, but there is room for an extension of their use. Even among the recognised fiery collieries, there are still some where furnaces are in operation, notwithstanding the generally admitted increase of risk, especially where it is possible for an outburst of gas to make the whole return air inflammable. Indeed, in any colliery, it seems to me that a fan is far more preferable than a furnace on the ground of economy as well as safety.

With regard to the falls on roads, it appeared that in 13 cases out of the 27, the deceased were in no way responsible for the safety of the roof and sides. In only a few cases of accident was it admitted by those who had the opportunity of examining the places prior to their occurrence, that there was any sign of danger. Yet, upon inspection after the accident, it was in several instances plain that, had the examination of the place by the competent person been such as is required, followed by the steps necessary for the prevention of a fall, some at least of these accidents would have been prevented.

It is true that after most of accidents by falls, a slip, or a change of stone, or a fresh break in the roof is seen for the first time at the particular place where the accident occurs, but this, in my opinion, is not evidence that the accident is one which could not have been prevented. On the contrary, the very frequency of these contingencies is the strongest argument which can be adduced in favour of greater *precautionary* measures being taken. Indeed, a fall most frequently occurs from the failure to anticipate what the actual condition of the place may be as regards its safety, and from continuing to work with a feeling of security because it appears as safe at the moment as it did some time before.

In several of the accidents, even where the falls were of considerable extent, there were no supports at the places where the falls occurred. In a large number of cases it was clear that the supports were insufficient in number.

After two years' experience in this district, I am convinced that the supervision of the colliers' working places, where a majority of the falls occur, is not all that can be desired. The supervision is, I believe, generally given, but it is of too cursory a nature. I take every opportunity of impressing on owners and managers the necessity for supervision of a superior kind, so that the requirements of the 21st general rule may be enforced, and also of the responsibility which attaches to them in case they fail to enforce its proper observance. This rule, which is a re-enactment of the 16th general rule of the Act of 1872, if it means

anything, means that the roof and side shall be secured in such a manner that persons may work with safety. It is not always sufficient to say that the roof, or the coal within a given area at the face, is itself strong enough, and needs no artificial support during the time the miners are exposed to it. All experience proves this to be delusive. No doubt there is a limit to the number of props which can be fixed in a working place, but as accidents are most frequent in places where more props could, without undue inconvenience, have been set up, than in places closely timbered, it seems to me that more systematic propping is necessary to reduce these accidents to a minimum.

Although the year passed without any explosion of gas, which could be attributed to the use of explosives, there is no denying the fact that the provisions of the new Act, whereby shots may, under certain conditions, be fired during the shift, with hundreds of men in the pit, make it possible for explosions to happen which may be more disastrous than any that have hitherto occurred. A shot-firer may neglect to comply with the conditions laid down by the 12th general rule, or may commit an error of judgment in considering a place safe which is not safe. I am glad to say, however, that owners and managers have—very wisely, I think—not taken advantage of the new regulations. So far as I know, there is only one colliery where shots, formerly fired between shifts, are now fired during the shift.

The universally admitted danger from shot-firing in fiery collieries should deter owners and managers from permitting the use of explosives therein, except where its use cannot be dispensed with, as in some kinds of stonework. Although no gas may be visible at the time, there is certain to be gas issuing, and likely enough hidden accumulations between the layers of roof immediately overhead, or in the floor of the seam.

Further, I am of opinion that, where there must be blasting in fiery collieries, the conditions under which it can only be carried out on a main haulage road or a place contiguous thereto, which is dry and dusty, should be applicable to all roads and air-courses.

In my Report for 1887, I referred to the system of watering the roadways by pipes, which has been adopted in many of the larger steam coal collieries, and I am glad to say that this is being extended. There cannot be any doubt that the liability of an explosion to spread is much reduced where the roads are moderately damp.

I regret to report that general rule 36, under which the persons employed may appoint two of their number, or any two practical working miners, to inspect the mine, is not taken advantage of to the extent which is desirable. Besides being a useful check on the officials, such inspections, made by different men from time to time, and to all parts of the workings, air-courses, and communications to outlet shafts, would familiarise the workmen with the various ramifications of the mine. Now that the owner, agent, or manager is bound to

send a copy of the report, when such report states the existence or apprehended existence of any danger, to the inspector of the district, workmen should not scruple to employ the legal means afforded them of examining into matters affecting their general safety.

Appended to the reports of Mr Dickinson (p. 23) and Mr Scott (p. 3) are the questions put to candidates for first-class managers' certificates in their districts in 1888.

J. B.

Transactions of the MIDLAND INSTITUTE.

MINING IN THE MIDDLE AGES.

By G. B. WALKER, F.G.S. Vol. XI., p. 175.

ABOUT the year 1550 George Agricola published a book in Latin wherein mining operations as conducted in Germany in the sixteenth century, and also the reduction and treatment of iron ores, are exhaustively described. Mr Walker's paper is a translation of parts of this book dealing more directly with mining and mining appliances, and is based on an edition dated 1657, and published at Basle. In his introduction, Agricola corrects the impression, which he says was common in his day, that mining reaches not the "dignity of an art." In doing this he points out that not only must the miner know mining thoroughly, but he must, in addition, have some knowledge of almost every other science, and even a little law will not be amiss. Finally he counsels those who would understand the rules of the art of mining to give "careful and diligent heed to what is set down in this book and in our other works," and if they would enquire further "consult such miners as are of skill and experience," and who are what we would now call specialists.

Having quoted the introduction, Mr Walker confines his attention to descriptions of typical examples of mining methods and appliances described by Agricola, illustrating the same by reproductions of the crude woodcuts of the book. Metalliferous mining only is dealt with, and it is surprising how like the conditions then were to those of the present day. The descriptions of the mine itself and of the housing at the surface

might be of the present, but the methods of getting the ore have more of an old world flavour. In a vein of very hard character, where fire cannot be employed, wedging must be resorted to. "The rock above or below (if more yielding) should first be removed, then a little above the vein should be placed beams so as to form a roof or floor, and in the next place beginning from the front, and the upper part where the rock shows minute cracks, nicks should be made with the tools most suitable for the purpose. In each of these nicks four wooden wedge feathers should be inserted, or, for deeper holes, it may be necessary to use four small iron feathers. Afterwards single wedges are introduced between two of the wooden wedge feathers, and these are driven with hammers, so as to make the vein give forth a sharp, ringing sound, but when it begins to break away from the rock above or below a cracking is heard. As soon as this grows loud the miners retreat rapidly. The noise becomes deafening, and the vein stuff falls, and in this manner they bring down 100 lbs. weight more or less. If miners attempt to deal with a very hard rich vein of metal in any other manner so much rubbish falls with the ore that it can scarcely be picked out afterwards." It was not permissible to use fire without the sanction of the neighbouring mine proprietors. "A pile of dry firewood is made and lighted—one if the mine or gallery be low or two if it be high, and in this latter case one is placed upon the other, and both burn until entirely consumed. By the action of heat so applied, no very great portion of the vein is usually melted, but only certain coatings. . . . When the contents of a lode, or the fault-stuff, or the rock itself have been loosened by fire the miners bring it down, if fractured in the upper part, by means of poles, or if the rock is still hard iron bars are inserted into the crevices, if laterally fractured they use hammers. The fragments thus loosened fall, and if there is still resistance it is overcome by the pick."

In winding, the ore was raised in wooden buckets of about fifty gallons capacity—like our modern kettle—or baskets, and sometimes even bags of oxhide. Trucks or hutches with small wooden wheels on iron axles ran on wooden planks, and were kept from slipping off the runners by a wooden pin running in a groove between the planks. These hutches were pushed by men, and were sometimes called "dogs" from the barking noise they made in running. The carrying of ore out of the mines does not appear to have been common. Water tubs were made narrow in the mouth, or formed of two bullhides sewn together, and attached directly to the winding rope. In winding machinery there were various appliances, such as the ordinary windlass, capstans, gins, and reversible waterwheels. Surface transport was by carts or sledges, and in winter dogs were employed in that work. In some mountainous districts the mineral was placed in skin bags and dragged down over the snow by men, and thence to the smelting works by pack mules.

Several machines for raising water were in use. One of these was formed of a double chain with buckets attached to each link. The chain

passed over a drum, with suitable grips for the chain, at the pit mouth, and dipped into the water in the sump. The drum was made to revolve by manual labour acting through a train of gearing. This gearing was of tempered steel. This machine was both slow and costly, and where more work required to be done a treadmill arrangement worked the chain drum without the intervention of any gearing. But the apparatus most in favour by Agricola is the ordinary lifting pumps worked by hand, horse, or water power. A pump worked by a water wheel is sketched and described, and in this case the water is raised by two lifts, a height in all of between forty and fifty feet. For greater depths the pump used was what we now know as the chain pump.

For ventilation the force of the wind was utilised by dividing the shaft into four compartments by cross brattices and carrying these brattices above the level of the surface. Against them the wind impinging was directed downwards into the mine from whatever direction it might blow. Bellows were also in use, and were applied to exhaust the air from the mine. The application of fans to ventilation was anticipated in those early days, but the fan in use was formed of radial blades revolving in a wooden case. The air entered at the circumference at one point, and was discharged at another into the mine, and this was considered the most satisfactory ventilating machine in use. In those days miners were liable to the enmity of goblins and demons, which we now recognise as the less poetic but no less deadly forces of nature. J. H.

Transactions of the MIDLAND INSTITUTE.

ELECTRICITY AS A MOTIVE POWER.

By G. B. WALKER. Vol. XI., p. 317.

THE first half of this paper gives an elementary description of the principles on which electricity is generated and applied to the production of mechanical effects. The latter part is devoted to a description of an electric locomotive worked with accumulators made by Immisch & Co., and designed by the author, for underground haulage. There is also a very short account of experiments with the locomotive applied to surface haulage at Wharncliffe Silkstone Colliery. J. H.

Transactions of the CANADIAN SOCIETY of CIVIL ENGINEERS. Vol. II.

A MINE PUMP WORKING UNDER A HEAVY PRESSURE.

By Mr H. S. Poole. P. 401.

In the Pictou coalfield the practice is to win the seams by slopes started from the crop, and as there is little water at the higher levels it is allowed to follow down as the slope is prolonged. At Westville, a range of plunger pumps had been extended down 800 yards to the foot of an incline of 1 in 2½, at which point the appliance reached the limit of its capacity, and a duplex compound condensing engine was substituted. The cylinders are pairs of 22in. and 12in. in diameter, the four water plungers being 5½in in diameter, and the stroke of engines and pumps 2ft. The column is 800 yards long, with a rise of 977 ft. vertical, and consequently a pressure at the plungers of 424lbs. per square inch. The loss of steam pressure in a length of 870 yards of covered four inch pipes is about 10lbs. per square inch. These pipes on the slope had a tendency to draw downhill, and instead of ordinary expansion joints, which failed to give relief, bends and circles are put in about every 150 yards. The delivery pipes are of wrought iron, with the ends screwed into thick metal flanges, which are plain faced, but one of each pair has a recess 1-16th inch deep, to hold in position a rubber ring ⅛th inch thick by 1½in. broad, and this joint, it is stated, has kept perfectly tight. Although there are four plungers throwing a steady stream, yet when started without an air chamber there was a variation of pressure of 160lbs. per square inch. The addition of an air vessel 4 feet long and 15 inches in diameter, with proper means of charging, reduced the shock to less than 20lbs. per square inch. A small hydraulic engine taking power from the rising main, raises the water from the lower sump to the steam engine.

J. G.

Transactions of the AMERICAN INSTITUTE of MINING ENGINEERS.

THE PRESENT STATUS OF ELECTRIC TRANSMISSION OF POWER.

By Mr Richard P. Rothwell.

The practical applications of electricity develop apace, and the object of the writer is to make note of the present position of the art of applying it to the transmission of power, and to endeavour to make out the track for a short way ahead.

From information furnished by the best manufacturers, the following

approximate estimates are given, to convey an idea of what responsible contractors will guarantee at the present time :—For transmission to a distance of one mile, an efficiency of 80 per cent. will be guaranteed at a cost of £16 to £17 per horse power for electric plant, and the total cost, including motive power (steam engine or turbine) will be from £24 to £26 per horse power. For transmission over five miles, an efficiency of 70 per cent. will be guaranteed at a cost of about £27 per horse power for electric machinery, and a total cost of £38 per horse power ; and if the distance be ten miles, the guaranteed efficiency is 50 to 55 per cent., the cost for electric machinery being £40 to £42 per horse power, and the total cost, including turbine and line wire, say, from £56 to £58 per horse power.

A description is given of several power installations at mines. One in course of erection at the Comstock mines, Nevada, is to be driven by six Pelton impact water wheels, 40 inches in diameter, which have the water discharged on to them through ½ inch nozzles at a pressure of 707lbs. per square inch. The shaft of each water wheel carries a dynamo of 135 horse power, which drives a motor of 90 horse power.

By way of comparison it is stated that in a large air compressing plant in Michigan, driven by turbines developing 1430 horse power, the indicated horse power given out by the engines at the works, three miles distant, is only 27 per cent. of the power driving the compressors.

The writer seems sanguine that means may be devised for controlling with safety pressures as high as ten or twenty thousand volts, and draws a picture of the effect which this would have, particularly on the coal and railway industries ; and he thinks it not improbable that before many years have passed coal will be burnt in highly economical furnaces at the pits, and the energy transmitted through wires to the great manufacturing centres, much cheaper than by the present system of railway transport and distribution by carts. J. G.

Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. 91.

ACCIDENTS IN MINES.

By Sir FREDERICK A. ABEL, C.B.

THIS volume contains the second part of an elaborate paper on "Accidents in Mines," and the subjects taken up are "Barometric Pressure as a Factor in Colliery Explosions in connection with the Escape of Gas from Goaves," "The Influence of Coal Dust in Causing or Intensifying Explosions," "The Watering of Dusty Mines," "Prevention of Blown-out Shots in Dusty Mines," "Accidents from Explosives," "Various Suggestions for Safety Cartridges," "The Water Cartridge,"

"Kossman's Safety Cartridge," "The Lime Cartridge," "Fuzes," "Electrical Firing of Blasts," "Miners' Lamps," "Defects of the Stephenson, Davy, and Clanny Lamps in Modern Mine Working," "Prize offered by Mr Ellis Lever for a Safety Lamp," "Addition of Glass Cylinders to Lamps of the Clanny Type," "The Mueseler Lamp," "Lamps of Smethurst and Ashworth," "Results arrived at by Various Experimenters on Lamps of the foregoing Types," "The Bonneted Lamp," "Modes of Closing or Locking Safety Lamps," "Defect of Want of Light in some Modern Forms of Protected Lamps," "Illumination of Mine Roads and Workings," "Miners' Portable Electric Glow Lamps," "Lamps of Swan, Pitkin, Coad, Schanschieff, and Others," "The Relative Advantages of Primary and Secondary Battery Lamps." The paper deals with the whole of the subjects which had been brought before the Government, in the Report of the Royal Commission on Accidents in Mines, of which the author was a member; and some additional information is given on the questions of explosions, blasting, and safety lamps which is not contained in that report. J. P.

Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. 91.

ELECTRICAL TRAMWAYS.

THE BESSBROOK AND NEWRY TRAMWAY.

By Edward Hopkinson, M.A., D.Sc., C.E.

Although much discussion has taken place during the last few years on the applicatien of electricity to locomotion, comparatively few attempts have been made at its practical realisation. The first electrical railway in the United Kingdom, constructed between Portrush and Bushmills, in the north of Ireland, was opened for traffic in October, 1883, and has since been extended. In 1883 a line was constructed along the foreshore at Brighton, upon which a single car has since been running regularly. There is also a short length of line in operation at the pier at Ryde. On a larger scale is the tramway along the promenade at Blackpool, two miles in length; but in none of these instances has any attempt been made at the regular haulage of minerals or goods, nor at the moving of cars larger than the ordinary tramway type. The total length of the Newry and Bessbrook line is 3 miles and 2 chains, and the average gradient is 1 in 86, the maximum gradient being 1 in 50. The guage is 3 feet, and the rails are at present single. Each terminus is a loop of 55 feet radius, so that the cars do not need reversing except in shunting. The locomotive car, with dynamo, &c., weighs 8¼ tons, and the passenger cars about 5½ tons, and they accommodate 44 passengers. The

generating machinery is fixed at Millvale, a distance of 68 chains from the Bessbrook terminus. At this point there is an available fall of 28 feet in the Camlough stream, down which there is a minimum flow of three million gallons per day, actuating an inward flow vortex turbine. The capacity of the wheel is 1504 cubic feet per minute, and, when running at 290 revolutions per minute, should develop 62-horse power. There are two generating dynamos of the Edison-Hopkinson type, but one is found to be sufficient for working the line. The conductor is of channel steel laid midway between the rails, and carried on wooden insulators attached to the sleepers, and the circuit is completed by the rails of the permanent way, which are uninsulated. The trains are commonly composed of one locomotive car, and three or four trucks, and a gross load of 30 tons is constantly drawn at a speed of 6 or 7 miles per hour on a gradient of 1 in 50. According to the author, this system of haulage compares favourably with that of cable haulage. Thus, in San Francisco cable tramways system, an average of only 32 per cent. of the total indicated horse power is available for moving cars and passengers, while on the Bessbrook and Newry electrical tramway 54 per cent. is obtained. In instituting this comparison, both systems are to be considered as working under conditions calculated to favourably develop the characteristic features of each. J. P.

JOURNAL of the FRANKLIN INSTITUTE.

SOME DIFFICULTIES ENCOUNTERED IN THE OPERATION OF PUMPS, AS MET BY THE "POSITIVE PISTON PUMP."

By JOSIAH DOW. Vol. CXXVIII., P. 161.

PLUNGER pumps can be applied to raise a column of fluid against any pressure; but, since they must be reciprocating, there is great loss in overcoming the inertia of the water and the resistance of the valves. These losses are avoided in the centrifugal system, which permits of a high velocity, but there is little or no suction, and the power necessary to drive pumps of this class increases in a much higher ratio than the height of delivery—their efficiency varying from 24 to 60 per cent. when working against the lift, at which they perform their best duty, which is a head of about 15 feet. To attain higher lifts, "Rotary" pumps have been designed, and they also avoid the piston pump losses by inertia and valve resistance, but they have not competed successfully with reciprocating machines. In 1885, however, a series of tests were made on one of the most approved construction by the Philadelphia Water Department. The water flowed into it, and the head to be overcome was 129 feet. The

effectual horse-power given out at its best velocity was 63 per cent. of the indicated horse-power. All this leads up to a description of an ingenious arrangement called the "Positive Piston Pump." It is of the rotary class, and the water comes in by a cylindrical pipe surrounding the axis of motion. The cylindrical pipe carries a blade which sweeps an annular chamber, sucking in the water behind it, and at the same time, on its advancing side, forcing the water into the discharge. The blade is the piston, and the suction and discharge pipes are separated by a revolving abutment rolling in contact with the cylindrical suction pipe. A portion of the abutment is cut away to allow the blade to pass through. There is one valve at the mouth of the discharge, which is required to establish the suction ; but when that has been attained it can be fastened out of the way, leaving the outlet unobstructed. As one blade moving rapidly would be unbalanced, the machine is duplicated. No experimental results are given, but it is stated to have "been put into practical and daily use, with both large and small volumes, high and low lifts, and shows great economy of power, with steady and quiet flow, at high or low speeds. It can be run for moderate lifts without frictional contact of the working part—the water itself, in grooves, supplying a packing, and momentum preventing slips, or it can be packed with a self-lubricating packing to prevent slip at any speed or pressure. It will readily establish its own suction, through use of the suction valve in the discharge, and yet leave the passage perfectly free for the flow of water." J. G.

JOURNAL of the FRANKLIN INSTITUTE.

AN INVESTIGATION OF SOME EXPERIMENTS ON A CENTRIFUGAL BLOWER DELIVERING AIR INTO THE ATMOSPHERE AT LARGE.

By Chief Engineer ISHERWOOD. Vol. CXXVII., P. 283.

THE experiments were made on a Sturtevant six-bladed blower, the outside diameter over the vanes being 12½in., and the inside diameter 7in. The area of each blade was 9·36 square inches, and the speed varied from 1250 to 1950 revolutions per minute. The air delivery measured 30 square inches, and the area of the inlets was nearly 2½ times as great. The velocities were measured by a sensitive anemometer placed in the delivery pipe with its axis mid-way between the centre and side, and the impact pressure was registered by a water guage, one leg of which was inserted horizontally at the same position.

The paper concludes with the following generalizations from and within the limits of the experiments :—

(1) The quantity of the same air, volume and weight delivered by the blower per revolution, is constant, let the number of revolutions made in a given time be what it may.

(2) The velocity of the air delivered is in the direct ratio of the number of revolutions made by the blower in a given time.

(3) The velocity of the centre of the surface of the fans is the same as the velocity with which the air is delivered.

(4) For any number of revolutions of the blower in a given time, the air pressure above the pressure of the atmosphere, reacting against the surface of the fans, and existing in the annular space between the periphery of the fans and the circular side of the blower case, and (the pressure ?) causing the velocity with which the air is delivered, is equal.

(5) The velocity with which the air is delivered at the outer end of the delivering cylinder is the velocity due to the excess of the air pressure at the inner end of the delivering cylinder above the atmospheric pressure. This excess of pressure being known, the velocity can be calculated, and, *vice versa*, the velocity being known, this excess of pressure can be calculated.

(6) The velocity with which the air is delivered at the outer end of the delivering cylinder is in the ratio of the square root of the above excess of pressure. Inversely, the above excess of pressure is in the ratio of the square of the number of revolutions made by the blower in a given time.

(7) When the velocity of the air is suddenly extinguished, the same excess of pressure above the atmosphere is reproduced that caused the velocity.

(8) The work done by the fans upon the inflowing air is measured by the above excess of pressure per square inch, multiplied by the aggregate area of the fans in square inches, and by the velocity of the centre of surface of the fans in feet per minute. This, however, is by no means the work done by a motor driving the blower, as such work must include, additionally, the difference between the quiescent atmospheric pressure and the pressure of the inflowing air against the back of the fans, and the friction of the motor.

(9) The work done by the outflowing air is measured by the above excess of pressure per square inch, multiplied by the cross area of the delivering cylinder in square inches, and by the velocity of the outflowing air in feet per minute.

(10) As the velocity of the centre of surface of the fans is the same as the velocity of the outflowing air, and as the pressure above the atmospheric pressure produced by the fans upon the air is the same as the pressure producing the velocity of the outflowing air. the work done by the fans on the air, and the work done by the outflowing air, are in the direct ratio of the aggregate area of the fans to the cross-area of the delivering cylinder.

(11) The number of cubic feet of air delivered per minute is measured

by the cross-area of the delivering cylinder in square feet, multiplied by the velocity of the air issuing from that cylinder in feet per minute, and by 0·82 for the co-efficient of discharge.

(12) Of the entire quantity of air entering the blower and put in motion by the fans, one-third is first brought to rest within the blower case, after which it is again set in motion by the fans with its original velocity.

(13) The theoretical co-efficient of the blower as a furnisher of air is two-thirds, including the air leakage; its practical co-efficient does not exceed 30 per centum.

(14) The resistance of the blower is as the square of the number of revolutions made by it in a given time. The power required to drive the blower, irrespective of the motor, is as the cube of the number of revolutions made by it in a given time. J. G.

JOURNAL of the FRANKLIN INSTITUTE.

ATKINSON'S GAS ENGINE.

Vol. CXXVII., P. 409.

THIS is a report by a sub-committee of the Committee on Science and the Arts to whom this engine was referred for examination. In order that the operation and special features of construction of the engine might be readily understood, the committee have given a brief historical account of preceding inventions and their mode of action, beginning with the suggestion of Huyghens in 1680, to obtain power from the gases generated by the ignition of gunpowder, and the subject is followed down to 1876, when the Otto "Silent" gas engine appeared. In its cycle of working, the piston is first drawn outwards by the ignition of the compressed air and gas; on the inward stroke the piston clears out through the open exhaust the products of exhaustion; in the next outward stroke the supply of gas and air is drawn into the cylinder; the return stroke compresses this mixture into the chamber at the end of the cylinder, and this being ignited, gives propulsion to the piston during the next outward stroke, so that the piston is giving out work only during one outward stroke in every two revolutions, the motion being kept up for three-fourths of the whole period of running by the momentum communicated to the heavy flywheel. This cycle of working—propulsion, purging, charging, and compression—is that adopted in all the present economical gas engines, and the several modern inventions are for improvements in the means and methods of effecting its functions In practice, the high temperature of the exploded gases cannot be maintained in the working cylinders consistent with correct fitting of pistons, and the temperature has to be lowered by the circulation of

water through a jacket surrounding the cylinder, from which there results, of course, great loss of energy. To reduce this loss from conduction, it appears to be a practicable expedient to make the cylinders of large capacity, and with as little surface area as possible, and at the same time to use high piston speeds. The Atkinson gas engine endeavours to combine these points in a simple machine. The mechanical action is made clear by drawings and diagrams. "Instead of making the two revolutions of the crank shaft to procure one impulse from the explosion of gas and air, the piston of this engine is connected indirectly by a peculiar system of lever and link or connecting rod to the crank, so that when the crank makes one-half revolution the piston passes out to the front or open end of the cylinder, and returns close up to the back end thereof. In the next half revolution, the piston passes out midway toward the front end of the cylinder, and makes only a partial return stroke, during which time it receives and compresses a charge of gas. This is ignited, and the piston is propelled outward a full stroke in less than a fourth revolution of the crank, and returns close to the back end of the cylinder, displacing all the products of combustion from the previous stroke, and leaving the cylinder free to receive an entire charge of air and gas."

Two tests of the engine were made. In one experiment the machine developed 10·3 brake horse-power with an expenditure of 22·25 cubic feet of gas per horse power per hour, and in the other 8·6 horse-power was developed with 22·30 cubic feet of gas per hour per horse-power. It is calculated that the energy utilized was 18·1 per cent. of the theoretic heat in the gas, and that 26·8 per cent. was taken up by the cooling water, the balance being the loss by radiation, imperfect combustion, and friction.

The committee state that the conclusions indicated by the tests are that this engine "surpasses all preceding gas engines in simplicity, economy, perfection of regulation, and uniform steadiness of power." Its economy was such as to impress the committee "with the importance of the machine as a competitor with the steam engine as a generator of motive power."

J. G.

JOURNAL of the FRANKLIN INSTITUTE.

THE TRANSMISSION OF POWER BY ELECTRICITY.

By FRANK J. SPRAGUE. Vol. CXXVII. P. 161.

THIS paper does not deal with the mechanical details of dynamo and motor construction, but with the general conditions which must be met, and the varying phases which the transmission of power by electricity

may assume. It also discusses Mr Sprague's methods for the determination of the elements of a single transmission which he has developed in his own practice.

First is considered the transmission from a central station of a supply for an area of one to 100 square miles, in quantities varying from a fraction of a horse power up to 50 or 100 horse power. The author illustrates this system by referring to his own practice in Boston, New York, and New Orleans, there being in the various stations put together no less than 1200 machines, delivering from one-half to 30 horse-power, and operated under potentials running from 100 to 440 volts. The maximum distances attained in this class of work is about one mile, and the practical limit with 220 volt potential from a single station being about four square miles. By raising the pressure to 1000 volts the author considers it practicable to cover from a single station an area of 100 sq. miles. Where a great number of machines are used in different industries they are not all working at full power at the same time, and experience has shewn that only from 35 to 40 per cent. of the total capacity of all the machines in the circuit requires on the average to be provided for, so that although the actual efficiency of double conversion varies from 50 to 70 per cent., depending upon distance and pressure, the amount of power that may be contracted for will at least equal the steam power at the central station.

The second system considered is the transmission at constant potential with the motors applied under varying loads, at constantly varying points on the line, as in the case of electric railways. As an illustration, the Richmond Union Passsenger Railway is given. It has about 12 miles of track, and is working under a pressure of 450 volts. The most distant point of the road is about 3½ miles from the central station, which has a steam capacity of 375 horse power, the aggregate capacity of the motors on the carriages being about double of that.

The third method discussed is the transmission from one station to another at which there are a number of independent machines; each under a variable load, but running with constant speed, an example being the transmission to a stamp mill where the stamp batteries are actuated by independent machines. The most satisfactory method is stated to be to maintain at the receiving station a constant potential, and to use motors wound to be self-regulating.

Fourthly.—The transmission may be between two stations as last mentioned, without the addition of automatic regulation being essential. A plant on this principle is transmitting a distance of a mile at the mines at Aspen, Colorado, at a pressure of about 450 volts.

Fifthly.—The transmission may be with a single line over a long distance, with the motors distributed throughout the entire line, as is the case in the mining operations at the Big Bend Tunnel, California, where about a dozen machines, each developing from 5 to 10 horse power are in

use, and are supplied by two lines, of from 600 to 1000 volts potential, over a distance of eight miles from the central station.

Some special cases of power transmission are noted, and then interesting and practical formulæ for determining the elements of a single transmission of a given amount of power are entered into at great length. Mr Sprague emphasizes the fact that "no system of transmitted energy can be made profitable unless the cost of the same at the far end, including not only the actual cost of production but the capitalized value of the possibility of accident due to the fact that the prime source of energy is not under immediate control, shall be less for the transmitted energy than the price that would have to be paid for its production there by water, steam, or some other agency." The use of water as a prime source of energy he considers limited, and the future transmission by electricity to depend upon the fact that in many cases it will be cheaper to carry the energy on a wire by the shortest cut rather than pack it up in the shape of wood or coal on the back of a horse or mule.

At the end of the paper, long-distance-transmission charts are given, showing, graphically, the relation between efficiency, potential, and distance, and a table illustrates the cost of the various elements of an installation per horse power delivered by the motor. J. G.

Transactions of the CHESTERFIELD and MIDLAND COUNTIES INSTITUTION of ENGINEERS, Vol. XVII., P. 174.

MECHANICAL VENTILATION OF COLLIERIES, with a Description of a New Form of Enclosed Mine Ventilator.

By the Rev. G. M. Capell.

The writer says that massive, slow-moving fans are gradually giving place to small, fast-running machines, which, if properly constructed, have a longer life.

The first Capell fans made were single-inlet, open-running machines, without any casing and from 11 to 15 feet in diameter, and gave from 40,000 to 130,000 cubic feet of air per minute at 1″ to 2·7″ gauge. Finding that higher pressures were required, the inventor designed a closed fan 10ft. in diameter by 8ft. wide, with a separating disc in its middle, so that there was practically two single-inlet fans turning together on the same shaft. The inlets were 5½ft. in diameter, the case was spiral, and about one-third of the fan was open to the chimney. The fan is built in

two portions. The internal one consists of a cylinder 5½ft. in diameter, having port holes formed in its surface, and there are curved blades dipping into it. To the cylinder the outer vanes or blades are rivetted, and they are furnished with side cheeks. The chambers formed by the blades and cheeks of the outer fan are larger than those of the inner fan, so that, when in rotation, the air is discharged at a high velocity into the exhausted spaces between the outer wings, which have formed in them a depression due to the velocity of rotation. At 213 revolutions per minute and 3·1″ gauge it gave 100,085 cubic feet, and a useful effect in the air equal to 80·2 per cent. of the indicated horse-power of the engine. Mr Herbst, the reporting engineer of the German Mine Ventilation Commission, considers that one reason for the high useful effect of the Capell fans lies in the fact that the velocity from the inlet to the outlet remains practically unchanged.

Some notes are given on the German method of comparing fans by the effective mechanical yield of the whole plant connected with the fan, a deduction being made for the *vis viva* produced by the atmosphere on the inflowing air.

The paper is followed by an appendix containing a translation of an elaborate article by Mons. H. Bochet, Inspector-General of Mines, Paris, on "Experimental determinations of the results of the working of a New Fan (Capell) and the consequences deduced from these results." By a process of integration he finds that the mean depression or water gauge existed at a distance from the periphery of the cylindrical inlet tube equal to one-third of its radius—the depression at all points remaining sensibly proportional to the square of the speed of rotation. He found the mean longitudinal velocity practically equal to two-thirds of the maximum longitudinal velocity which existed at a distance from the periphery equal to one tenth of the radius of the inlet and his figures show that the work in the air entering the fan is superior to the motor force, the useful effect being 129 per cent. when exhausting with full open inlet from the still atmosphere. This result, at first sight paradoxical, is in good agreement with that got by Mr D. K. Clark. The useful effect of a fan estimated in the usual way is not its dynamic effect, which is the relation to the motor force of the excess of work contained in the outflowing air over that contained in the air flowing into the fan. He explains the high so-called useful effect to be due to a portion of the *vis viva* of the air entering the fan being given up within it and acting as an auxiliary to the driving engine, it being conceivable that air passing at a high velocity from the inner fan, striking the concave outer blades, which are curved in a contrary sense to the rotation, acts upon them with a motor force. By measuring the work in the air coming out of the fan he found that the true dynamic effect was only 72 per cent. Mons. Bochet concludes, "the Capell fan is very superior, in the proportion of 129 to 93, to the best fans actually known. To produce

the same useful effects it takes a much less motor force—less by about 30%, and it is not necessary for the fan to be so large. By giving it suitable dimensions you can obtain, at a much lower cost, any useful effects desired, both in water-gauge and in volume of air exhausted." J. G.

Transactions of the LIVERPOOL ENGINEERING SOCIETY.
Vol. VIII. P. 28.

THE BIRMINGHAM COMPRESSED AIR POWER SCHEME.

By JOHN STURGEON.

AUTHORISED by Act of Parliament, works are now being carried out in Birmingham by a Company for the public supply of power by compressed air. Previous to the passing of the Act, the corporation employed Sir F. Bramwell and Mr Piercy, who found that, owing to the intermittent character of the work done by the smaller class of steam engines in the district, they only averaged one-third of their maximum power with a coal consumption in the best example of 8½lbs., and in the worst of 36lbs. per indicated horse power per hour, upon the averaged daily indicated horse power.

The contractor for the gas producers and boilers guarantees an evaporation of 10lbs. of water per pound of Birmingham slack, and taking 15lbs. of steam per i.h.p. per hour, gives a fuel consumption of 1½lbs. per i.h.p. per hour. According to the method used the loss in compression and distribution will vary from 16 to 69 per cent., which is equivalent to a fuel consumption of 1·8lbs. to 4·8lbs. per hour per i.h.p. in the air. Great saving is of course effected by the substitution of a central plant for the boilers required by every user, and when the power is employed for diverse purposes, and at different times, the average horse power to be supplied falls a long way below the maximum needed by all the machines—the driven motors never being all in action at any one time.

The "district" authorised by the Act contains an area of 1½ square miles, and there are 23 miles of wrought iron main pipes, ranging from 7 inches to 24 inches dia., laid in concrete troughs, with solid concrete covers, and kept as near the surface as possible. The works are laid out for 15,000 indicated horse power produced by 31 of Wilson's 8 cwt. patent gas producers. The air is to be supplied at a constant pressure of 45lbs. per square inch and sold by meter, several forms of which give fairly accurate measurements of volume. Compressed air when laid on may be applied to as many purposes as any other source of power with the great additional recommendation that the exhaust is always advantageous in the rooms and workshops of a crowded city. Unlike steam it cannot be used for heating, but on the other hand it has applications for refrigerating.

J. G.

Transactions of the MANCHESTER GEOLOGICAL SOCIETY.
Vol. XX. P. 256.

ON CARBONIC ACID GAS OR BLACK DAMP, AS COMMONLY FOUND IN MINES.

By Mr Joseph Dickinson.

A statement having been made that a party of scientific gentlemen had heard carbonic acid gas issuing audibly, with a hissing noise, in the Foxdale Lead Mines, Isle of Man, Mr Dickinson says that in all his experience he had never found this gas given off with a sound, which agrees with the experience of several of his mining friends. The principal agent at the mines also states that he had never heard it blowing or singing, but had often felt it coming out of small "pipes" like cold air blown on the back of the hand through the stem of a tobacco pipe. J. G.

THE SCHOOL OF MINES QUARTERLY. Vol. X. P. 123.

THE TRANSFORMATION OF ELECTRICITY INTO MECHANICAL ENERGY.

By W. H. Erb,

This essay gives a description of the action of motors and a mathematical demonstration of Jacobi's law that "the mechanical work done by an electro-motor is at a maximum when it is geared to run at such a speed that the current in the dynamo is reduced to one-half what it was when the motor was at rest," but practically it is found more economical to make the speed of the motor two-thirds that of the dynamo.

The distribution of the energy in electrical circuit is also dealt with mathematically, and the following table is given showing the cost in dollars of transmitting energy equal to 100 horse-power over the distances stated:—

	330 Ft. D.	16,400 Ft. D.	65,600 Ft. D.
Electricity,	1·80	2·27	4·61
Water Power,	2·27	4·03	9·57
Compressed Air,	3·17	4·05	6·39
Wire Rope,	1·26	2·88	12·68

J. G.

THE SCHOOL OF MINES QUARTERLY. Vol. X.

LIST OF BOOKS ON MINING.

By Professor H. S. Munroe. P. 176.

This list was prepared for the use of the students in the School of Mines, Columbia College, and includes American, British, and Continental

works, divided into—General treatises on mining; mining machinery; metal mining; coal mining; elementary treatises on mining; popular works on mining; mining societies; mining journals; Government and State reports; indices to periodical literature; mine surveying: hydraulic mining; well boring; shaft sinking; tunneling; mine timbering; mine ventilation; mine drainage; haulage; hoisting and surface transportation; ore dressing and coal washing; and accidents in mines.

J. G.

Minutes of Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. XCV. Foreign Abstracts.

Stone-Cutting and Quarrying by Wire. P. 424.

("L'Industrie Moderne," 1888—pp. 203-218.)

THE "Helicoidal Wire" system is employed for quarrying and subdividing marble in the old Roman quarries at Schemton, in Tunis, and at other places. Power is transmitted by wire rope to the highest point of the quarry, whence it is distributed by three helicoidal cords, each composed of three steel wires twisted spirally, and running at the rate of 14ft. 9ins. per second. The cord, with the aid of sand and water, which is kept constantly flowing in the groove, cuts the marble at the rate of 5 inches per hour. The diameter found most suitable is less than a quarter of an inch, and its helical twist gives a rotary motion, resulting in an even wear of the wires.

The direction of the cords may be changed by means of pulleys, which are fed down as the stone is cut, and the same cord may be made to serve several working places. In order to permit of the cutting cord descending into the solid rock, it is necessary to sink shafts at all angles of the quarry, which is done by annular drills driven by wire rope, the cores produced being used for columns.

Wilmsmann's Smoke-Consuming Furnace. P. 464.

By — SEILER, of Mannheim.

("Journal für Gasbeleuchtung und Wasserversorgung," 1888 – p. 135.)

THIS simple and cheap smoke-consuming and fuel-economising arrangement is due to Mr Wilmsmann, Mining Director of Hagen, Westphalia, and has been applied to about 600 furnaces in the Rhenish provinces, Westphalia, and the South German States.

The front part of the furnace is converted into a generator chamber by a fire-brick shield and division wall above the fire-bars, near to the

bridge of the furnace, to keep the gases and smoke from going direct to the flues. In starting, the fuel is burnt for three-quarters of an hour in the usual way, and the incandescent layer of fuel is gradually pushed back to form an inclined heap against the baffle, thus closing the combustion chamber from the fire space. The carburetted hydrogen combines with the air entering through the fire-bars, and the coal, partly converted into coke, burns with a further supply of air. The gases formed over the red-hot coals are conveyed, through channels at the top of the furnace, into a back chamber, where they are burnt with a secondary hot-air supply introduced through channels regulated by dampers. The formation of smoke after supplying fresh fuel is entirely avoided if the gas-chamber is separated from the fire space and flues by the glowing layer of fuel.

The economy of the arrangement is stated to vary from 15 to 30 or 40 per cent. over ordinary furnaces. A Cornish boiler, fired in the old way, evaporated 6·35 lbs. of water per lb. of coal consumed ; and the same boiler, fitted with Wilmsmann's furnace. yielded 9·5 lbs. of water per lb. of the same fuel.

The chief engineer of the Berg Steam Boiler Examination Society speaks of the furnace as "sound in principle, of great simplicity, and small in cost for fitting."

Diminution of Earth Temperature in Deep Mines. P. 471.

("Oesterreichische Zeitschrift für Berg-und Hüttenwesen," 1888 —p 199.)

At Pribram, meteorological observations made in the Adalbert Mine, at a depth of 547 fathoms, show that the temperature of the rock, taken in an enclosed space protected from draughts, where the air temperature has remained constant at 24° C. for five years, has been gradually diminishing at the rate of one-tenth of a degree centigrade per annum since the observations were commenced.

An Apparatus for Measuring Earth Pressure Underground. P. 471.

("Zeitschrift für das Berg-Hütten-und Salinenwesen," 1888—p. 214.)

The apparatus is really for measuring earth movement—the movement of roof and floor relative to the side of the excavation. A wooden plug, a yard long, is driven into a hole in the floor, and another one into a hole in the roof vertically above it. Short lengths of iron tubing are screwed to the ends of these plugs, and nearly meet in the middle, a connection being made between them by a guide pin on the lower tube sliding within the upper one. The movement of the ends of these tubes is multiplied by a pair of levers which trace the motion on a board firmly clamped to the side wall.

Differences of Level in the Mines of Austria and Hungary. P. 472.

By F. R. M. von Friese.

("Oesterreichische Zeitschrift für Berg-und Hüttenwesen," 1888—p. 321.)

In this paper, the depths of some of the deepest of the Austro-Hungarian shafts are given. In Pribram, the Maria shaft is 591 fathoms deep; the Adalbert, 584 fathoms; the Anna, 515 fathoms; and the Franz Joseph and the Procopi, 482 fathoms each.

On the Relations between Seismic and Atmospheric Disturbances and the Disengagement of Fire-Damp. P. 473.

By G. Chesnau.

("Annales des Mines," vol. xiii., 1888—p. 389.)

At the Herin Pit of the Anzin Coal Company, observations were made with a tromometer, consisting of a pendulum 4′ 11″ in length, suspended from an iron pivot fixed in a thick wall. Wind and local vibrations caused by passing vehicles produced no appreciable effect on the apparatus. From the percentage of gas found in the return air-courses, the daily amount given off was determined. A diagram was prepared, showing the intensity of the seismic movements, the barometric readings, and the amount of fire-damp given off for the period from February to December, 1887. Taking into account only the more marked variations of the curves, there are 43 concordances of the tromometer with the fire-damp curve, to 17 discordances; and 11 concordances of the barometer with the fire-damp curve to 9 discordances. It would, therefore, appear that the connection between seismic disturbances and disengagements of fire-damp is fairly demonstrated, but that the influence of barometric variations is not so well established. Whenever a large increase of fire-damp has been maintained for several days, there is a very remarkable coincidence between all the three curves.

Shaft-Sinking by Haase's Method. P. 475.

("Zeitschrift für das Berg-Hütten-und Salinenwesen," 1888—p. 225.)

This method was employed at the lignite mine of Guerini, near Cottbus. A pumping shaft, 10¾ feet by 8½ feet inside the timber, was sunk a depth of 20 feet, when the flow of water and sand became so great as to endanger the work, and the sinking was continued by Haase's method, which consists in driving down side by side a series of wrought iron tubes to form an inpermeable wall, the ground being partially drained by the flow of water from the tubes. The shaft was reduced to 9½ feet by 7¼ feet within the wall of tubes, which were 4½ inches in external diameter, ⅛th of an inch thick, and made in 13 feet lengths. The depth of ground was 12 fathoms, requiring six sets of the patent tubes, of which 18 rows

were used on the longer sides, and 14 rows on the shorter sides of the shaft. In order to get them down straight, guides fitting their curvature were made fast to the top timbering. The total cost of the lining, including material, tools, wages, supervision, and fuel, was £2102.

Cast Iron Tubbing for Lining Levels. P. 476.

("Zeitschrift für das Berg-Hutten-und Salinenwesen," 1888—p. 230.)

At the Eschweiler-Reserve Mines, near Düren, cast iron tubbing in segments as used in shaft sinking, has been successfully employed in driving a level through ground broken up by faults. The tubbing is 7ft. 8in. outside, and 6ft. 9in. inside dia.; the breadth of flanges 5½in., and the thickness of metal in the body 1½in. The segments are 29½in. long, and there are eight in the circle. The top segments required to be lifted eight feet overhead, and were fixed with the aid of a special erecting carriage.

A Winding Engine with Spiral Balance Drum. P. 484.

By K. Habermann and J. Von Hauer.

("Berg-und huttenmannisches Jahrbuck," 1888 — p. 120.)

The Camphausen Colliery at Saarbrücken is 270 fathoms deep, and the winding engines have two cylinders, 48 inches in diameter, coupled direct to a cylindrical drum, 26ft. in dia., and 11ft. broad. The balance drum is a double spiral, rising from 10 to 33 feet in diameter, with a rope track for 28 revolutions. It is coupled to the winding drum by a crank, and moves with the same speed, but in an opposite direction. The two ends of the balance rope are fastened to the drum at its smallest dia. The rope goes down the balance pit (262ft. deep). round a loose pulley carrying the balance weight of 15 tons, up the balance pit again, and back to the drum. At the commencement of a winding, the balance rope uncoils from the larger diameter of the spiral, and winds up on the smaller part, so that the balance weight descends—faster at first until the cages reach mid-shaft, when the balance weight becomes stationary owing to the rope running on groves of equal diameter. After this the counterpoise rises as the larger diameter now takes up rope and the smaller end of the drum pays it out.

The Beer System of Wire Ropeways. P. 485.

By Charles Raoult.

("Revue Universelle des Mines, 3rd series, Vol iii.," 1888—p. 49.)

At the Seraing furnaces of the Espérance-Longdoz Coy., the slag is granulated and transported by the ropeway capable of carrying 130 tons per day of ten hours to a distance of 300 yards, the point of delivery being 160 ft. above

the starting point. The carrying rope for the full road is 1¼in. diameter, and is strained by a counterpoise of 5 tons 18 cwt., and the carrying rope for the empty road is 1 1-32in. diameter, and strained by a weight of 3 tons 18 cwt. A quarter turn over is occasionally given to these ropes so that they may be equally worn. They are supported on three intermediate piers. The hauling rope is endless, and 11-16th inch diameter, and travels at the rate of about 2¼ miles per hour, and is kept taut by a weight of about two tons. Thimbles are fixed on it every 38 fathoms to engage with clips on the skeps. These thimbles are made in halves and dovetailed together so as to be slipped on anywhere, and are secured by small rivets with countersunk heads, and their position is changed from time to time to avoid unequal wear of the rope.

On Siemens and Halske's Electric Winding Engine at New Stassfurt.

("Oesterreichische Zeitschrift für Berg und Hüttenwesen," 1888—p. 105.)

THE engine was stationed at the bottom of a shaft 197 fathoms deep, and hauled a loaded tub of 24 cwt. gross weight up an incline of 40°, and 170 yards in length, once in every three minutes. This load was partially counterbalanced by the descending empty tub, weighing 8 cwts. The machine was driven by a steam engine and primary dynamo at the surface, which had been previously erected for actuating an electric railway. It gave a current of 22 amperes and 370 volts, which was carried by bright copper wires on the surface, and by a covered cable laid in wooden troughs down the pit and underground, the total length of double conductor being 610 yards, and the leakage due to it is stated to have been only 5 or 6 per cent.

The secondary dynamo converts 75 per cent. of the electric energy into power, and makes a thousand revolutions per minute, driving an intermediate shaft by means of belting at about one-third of that speed, which was again reduced by spur gearing to 13·3 revolutions per minute of the rope drum, which was 4ft. 1in. in diameter, so that the rope moved about 3 feet per second. The useful electrical effect was at least 53 per cent., but 25 per cent. was lost by the driving gear of the drum, so that only 40 per cent. of the work of the steam engine at the surface was realised at the drum shaft below ground.

The transmission of power through a shaft driven by a belt has proved advantageous in preventing shocks at starting and stopping. The reversal of the current is effected by lifting or lowering one or other of a pair of brushes, placed diametrically opposite to each other in regard to the commutator.

The engine continued in use from November, 1885, to March, 1887, when the purpose for which it had been erected was accomplished.

The Poisonous Action of Water Gas. P. 508.

By HEINRICH SCHILLER of Zurich.

("Zeitschrift für Hygiene, 1888,"—p. 440.)

WORKMEN in a manufactory in the neighbourhood of Zurich were attacked by headaches, dizziness, vomiting, debility, &c., and the factory inspector satisfied himself that the illness was probably caused by the unconsumed water gas furnished by a Dowson generator. A number of experiments were made on animals, and the conclusions arrived at are as follows:—"As the gases are devoid of smell, it is only when evolved from fuel containing sulphur compounds that an odour of sulphuretted hydrogen is perceptible. Both gases are strongly poisonous. The symptoms are identical with those of poisoning by means of carbonic oxide gas. A fatally poisonous mixture is an atmosphere with about 1 per cent. in the case of water gas, and 1·5 per cent. in the case of Dowson gas. Symptoms of poisoning are produced by about 1 per mille with the former, and three parts per mille with the latter gas. In non-fatal cases a rapid recovery, as a rule, ensues. The poisonous principle is the carbonic oxide gas."

Alpine Engineering. P. 237.

By LEVESON FRANCIS VERNON HARCOURT.

THIS paper deals with the many railways which now cross the Alps, and the details it gives of the great tunnelling operations which have been undertaken in connection with three of them are of interest to miners. The first railways were the Semmering and the Brenner, which have only short tunnels, the first long summit tunnel being on Mont Cenis. It is 7·6 miles in length, and was driven from both ends in a perfectly straight line, rising 1 in 43½ from the French side, and 1 in 2000 to 1 in 1000 from the Italian side—solely for the purpose of drainage. It was commenced at the end of 1857, at first by hand, when the greatest advance made at both ends for the year 1858 was 502 lineal yards, as compared with 1788 lineal yards in the same material by Sommeiller boring machines during the year 1870. The greatest advance during a month was at the rate of 12·9 feet per day when traversing carbonaceous schist, and the least progress 1·17 feet per day when in quartz. The driving occupied 13 years and 1 month, and the average daily progress was 2·57 lineal yards for both ends. The total cost was equivalent to about £224 per lineal yard.

The summit tunnel for the St Gothard Railway was constructed after the experience gained on the Mont Cenis. It also is driven in a straight line from end to end, a distance of 9·26 miles. On the north side it mounts up at a gradient of 1 in 172, and on the south side rises at the rate of 1 in 500 to 1 in 1000 so as to allow the water to run out. The driving was commenced in September, 1872, and dynamite was introduced for blasting, gunpowder only having been employed at the Mount Cenis work.

The headings were communicated after a lapse of 7 years and 5 months, and the average daily advance for both ends together was 6·01 yards, or more than double the Mont Cenis rate. It cost about £142 per lineal yard. The temperature of the rock in the tunnel rose gradually as greater depths were reached, and towards its centre, where the maximum depth is 5,733 feet, attained an average of 86·7°, but two years afterwards this temperature had fallen 12°, and it was expected that it would eventually descend to 68°. The workmen suffered considerably from the effects of the high temperature, combined with the humidity of the air.

The third great tunnel constructed was the Arlberg, 6½ miles in length, and also formed in a perfectly straight line. It rises from one end at a gradient of 1 in 72, and from the other at 1 in 520. The headings were started in July, 1880, and were joined 3 years and 4 months later, equal to a progress of 9 yards per day for both ends. During 1883 each face advanced at the rate of 5·95 yards per day, equal to a mile and a quarter per annum. It cost £107 18s 2d per yard.

The paper also enters into details of the proposed railways and tunnels for crossing the Alps at Mont Blanc, the Great St. Bernard, and the Simplon. J. G.

Minutes of the Proceedings of the INSTITUTION of CIVIL ENGINEERS. Vol. XCVI. Foreign Abstracts.

Steep Wire-Rope Railway at Montreux, Switzerland. P. 406.

("Die Drahtseilbahn Territet-Montreux-Glion, von Emil Strub, Aaran," 1888.)

THE horizontal length of this railway, which has been working since 1883, is nearly 2000 feet. In this distance it rises 1000 feet, giving a mean gradient of 1 in 2, but for more than half of its length it rises at the rate of 1 in 1¾, and is, therefore, one of the steepest passenger railways in existence. It is a self-acting incline, actuated by a water balance, a maximum of 7 tons of water being required when the descending carriage is empty and on the flat part of the incline, while the ascending carriage is fully loaded and on the steep slope. The descent is regulated by two hand brakes on the down-coming carriage. These brakes control a cog-wheel, which gears into a rack laid between the rails from end to end of the incline. There is also an automatic brake, which is kept fully applied by means of a heavy weight sufficient to render the carriage immovable. When the rope is in tension, it lifts off this weight; but should it break or lose its hold, the weight falls down and brings the carriage to rest after only a few yards' descent. The result of five years' experience shows that these brakes work well. The gauge is one metre, and the speed is regulated to between two and three miles per hour.

Comparative Trials of Piston Pumps and Centrifugal Pumps. P. 423.

By — De Glehn.

("Bulletin de la Societé Industrielle de Mulhouse," 1888—p. 661.)

The works of Messrs Schaeffer, Lalance, & Co., at Pfastatt, use daily about two million gallons of water, drawn until 1885 from the River Doller by means of ten centrifugal pumps A well was subsequently sunk near the river, and from it a supply of from 20 to 45 gallons per second was drawn by means of two "conjugated" centrifugal pumps. Later, piston pumps were erected capable of discharging 90 gallons per second into the tank already constructed for the centrifugal pumps. The opportunity presented of making trials of the two systems of pumping, from the same well, with the same lift, and through the same discharge pipe, into the same tank of large capacity, was taken advantage of. The mean lift was about 36 feet.

The steam engine employed to drive the centrifugal machines had a cylinder 21·65 inches in diameter, and a stroke of 39⅜ inches, and was run at from 46 to 60 turns per minute, giving a speed in the pumps of from 470 to 611 revolutions in the same time. The work done in raising the water varied from 48·4 per cent. at the lower velocity to 34·72 per cent. at the higher velocity of the indicated work in the cylinder of the engine.

The piston-pumps and steam engines were made by Messrs Hathorn & Davey, Leeds—the engine of the horizontal compound receiver class, cylinders 19 inches and 33 inches diameter by 3 feet stroke, connected by bell cranks to four pumps, each 22 inches diameter and 3 feet stroke. This fitting worked well, and without shocks, at speeds up to 20 revolutions per minute. Engine and pumps together, including carriage, duty, and erection, cost £2160. The trials were made at speeds varying from 13·3 to 26·1 turns per minute, and the work done in raising the water varied from 73·8 per cent. at the lower velocity, to 64·6 per cent. at the higher speed of the indicated work in the cylinders—the trials showing a gradual diminution in the duty as the speed was increased.

Shaft-Sinking at the Houssu Colliery, Belgium, by the Poetsch Freezing Process. P. 432.

("Bulletin de la Societé de l'Industrie Minérale," 1888—Vol. ii., p. 21.)

In the sinking of the No. 8 Pit of the Houssu Colliery (13 feet in diameter), at a depth of 32½ fathoms, the solid bottom, estimated to be 5 feet in thickness, was suddenly thrown up, giving vent to a very wet quicksand, which rose 20 feet up the shaft, the water rising to within 82 feet of the surface. Including the 20 feet forced into the pit, it was found that 62 feet of sand had to be pierced before reaching solid ground.

Acting on the advice of Mr Poetsch, the sand was covered with a thick bed of concrete, and immediately above it the walls of the shaft were

chambered out about three feet all round. In this annular space eighteen freezing tubes were driven down right through the sand, and 8 to 10 feet into the solid strata below, and connected with the circulating apparatus on the surface. During the freezing, no attempt was made to keep down the water in the shaft, and owing to the inefficiency of the apparatus and other causes, a full year elapsed before sinking could be resumed.

A shaft eleven feet square was sunk through the concrete plug and frozen sand, but as no blasting was allowed, owing to the fear of disturbing the freezing pipes and the wall of frozen material, estimated to be ten feet thick all round, the progress made was only eighteen inches per day with three shifts of men, the frozen ground being very hard. An attempt was made to thaw out the core by means of steam jets, but they produced a soft mud into which the men sank mid-leg, and progress being slower still, this method was abandoned.

At a depth of 42½ fathoms three curbs were laid, and on them a lining of cast-iron tubbing, 13 feet clear diameter and 1⅝ inch thick, backed by a ten inch layer of concrete, was carried up, the shaft being enlarged as the work proceeded.

It was found that the freezing did not interfere with the setting of the cement. J. G.

Transactions of NORTH of ENGLAND INSTITUTE of MINING and MECHANICAL ENGINEERS. Vol. XXXVIII.—p. 49.

NOTES ON VARIATIONS IN FAULTING OF COAL.

By T. O. Robson.

In working a coalfield a certain fault was observed to vary considerably in three several seams, the second and third being 12 and 32 fathoms respectively under the first. To take one example, in the first and third seams a dislocation took the form of a definite trough fault, that is, a narrow strip of coal was lowered by two distinct faults down in opposite directions, 26 feet each, while in the second or middle seam at the nearest point proved 165 yards distant horizontally. The fault was a loop or fold merely. The peculiarity, however, lies more in the upper seam being most troubled, both in number and decisiveness of dislocations, the second less so, and the third comparatively free as if the faults died out in depth. The same variation characterises the quality of the coal, the two upper seams being much deteriorated, the lowest not at all. While the roof and pavement is much broken near the faults in the upper seams, the third is good throughout. J. H.

Transactions of NORTH of ENGLAND INSTITUTE of MINING and MECHANICAL ENGINEERS. Vol. XXXVIII.—p. 59.

OUTBURSTS OF GAS IN METALLIFEROUS MINES.

By BENNET H. BROUGH.

THE explosion of fire-damp in the Mill Close Lead Mine in Derbyshire has led to the collection of recorded cases of fire-damp having been observed in metalliferous mines. Although the paper is headed "Outbursts" of gas many of the instances referred to are not "Outbursts" in the ordinary acceptance of the term, but simply the more or less regular discharge of gas characteristic of coal mines which give off fire-damp. The Yoredale shales have been long known to give off fire-damp, and the explosion at Mill Close is not the first in metalliferous mines of the district. A book, written in 1734, on "The Mineral Waters of Derbyshire," records the existence of hollow boulders which contained bitumen, and of several springs in the mines which burned for days if lighted. "Several damps have happened in these mines without any preceding visible cause or sign, but all being serene and clear in the works without fog or mist, the sulphur in the air would fire at the miners' candles, the flame run from one end to the other with a thundering noise, making the earth shake, and in two moments the sulphur was spent, the fire extinguished of itself, and all clear again. The only shift the workmen have is to clap down on the earth instantly on their faces till it is over." Fire-damp, or rather, inflammable gas, has been frequently found in the salt mines of the Continent. Its presence is attributed to hydro-carbons from decomposing vegetable matter. It has been known to exist in such quantities as to be utilised for lighting and heating purposes. Numerous other instances are given, many of them in fissure vein mines. The origin of the gas is attributed to decay of wood in flooded adit levels, in two cases of explosion which occurred when these levels were holed into. Similar phenomena were observed on removal of dams in two cases, the gas being in both said to come from decaying wood, but the evidence of this being the true cause is not stated, while several instances are mentioned wherein, with apparently equally favourable conditions, gas was present on draining, flooded, and heavily-wooded levels. Sulphuretted hydrogen has been frequently met with in Peruvian mines. An old chronicler speaks of a mine called the "Stinking Mine," from the prevalence of this gas, which finally caused its abandonment. The occurrence of carbolic acid gas in Derbyshire mines is mentioned in an account by a miner published in 1747. This author records instances wherein a man "well steeped in ale" was able to descend and recover the bodies of miners overpowered by this gas, adding, however, that he "never yet knew of any man that was sober durst be so bold to take a sufficient dose of ale on purpose that he might the better encounter it."

The phenomena recorded are summarized and hypothetically explained

under six heads—(1) Decomposition of timber in a mine may produce fire-damp. (2) The conversion of a lower oxide of iron into a higher may take place, decomposing water, and liberating hydrogen in mines of iron ore. But (3) in cases that may be so explained, it is more probable that the gas was fire-damp from adjacent beds. (4) Fire-damp may be produced by decomposition of organic matter similarly to the hydro-carbons in salt mines. (5) Explosions have been caused by sulphuretted hydrogen, produced by action of acid waters on pyrites, ore. (6) Carbonic acid may, in instances mentioned, have been produced by action of acid waters, from the oxidation of pyrites on limestone or metalliferous carbonates.

J. H.

Proceedings of the SOUTH WALES INSTITUTE of ENGINEERS.

THE HYDRO-DYNAMIC PUMP.

By W. H. THOMAS. Vol. XVI. P. 191.

THE distinctive feature of this hydraulic pump is that a single pipe acts both as power pipe and discharge pipe. The pump proper consists of two rams rigidly fixed together, placed side by side—the one being indirectly a power ram, and the other the pump plunger. These plungers are loaded, and work on the principle of the hydraulic accumulator. Water under a head greater than the lift required is, by means of suitable valves, placed in connection with the discharge end of the pipes, and worked by a cataract and pendulum arrangement, admitted to the discharge pipe then acting as a power pipe in producing the return stroke of the pump. The water pressure thus obtained acts on the loaded power ram, raising it, and at the same time the pump plunger. The up or suction stroke of the pump thus completed, the power pressure is shut off by the cataract valve at the top, when the loaded piston falls, forcing the water up the rising column, now acting as a discharge pipe. With power head of 225 yards above the pump, or 100 yards above the discharge, the pump can raise water through a lift of 100 yards vertical when the quantity of power water required will be equal to the quantity lifted by the pump. With a greater head, a smaller quantity of power water relatively to what is pumped will be sufficient. The necessary pressure for the return stroke may, by a suitable arrangement, be obtained by mechanical means in place of head of water. This pump, on a small scale, has been at work in a South Wales colliery with, it is said, satisfactory results, but is obviously best suited for cases where the discharge is into an adit level.

J. H.

Proceedings of the SOUTH WALES INSTITUTE of ENGINEERS.

APPLICATION OF ELECTRICITY TO UNDERGROUND HAULAGE.

By JOHN FOX TALLIS. Vol. XVI. P. 124.

THIS paper is purely theoretical, having no reference to any particular instance of electricity being applied to haulage. Assuming certain data, the details of an electric plant suited to the requirements of the hypothetical case are minutely considered and detailed. It is, in short, a general specification of an electric haulage installation. J. H.

Proceedings of the SOUTH WALES INSTITUTE of ENGINEERS.

SINKING APPLIANCES at LLANBRADACH.

By W. GALLOWAY. Vol. XVI.—p. 107.

THE shaft sunk by the Cardiff Steam Coal Collieries Company (Limited), at Llanbradach, was put down for the purpose of ascertaining the exact depth to the coal, and to gain such information as to pumping requirements. &c., as would enable the engineers to determine with some degree of certainty the fittings of the future colliery. It is also intended to form the upcast when the winding shaft has been sunk. It was known that a considerable thickness of the Pennant sandstone series, which is invariably found heavily watered, required to be passed through, and surrounding collieries have heavy pumping fittings. The absence of any means of determining the probable quantity of water to be dealt with in sinking led to special provision for winding the water to the surface. The contract provided for certain allowances whenever the water exceeded 4000 gallons per hour, whether pumps were provided or not. The largest quantity met with was 7500 gallons an hour in the shaft bottom. Down to a depth of 135 yards the total growth was 9000 gallons an hour, of which 5000 gallons was walled out by brick and cement walling. It would have been impossible to proceed with the sinking without pumps had it been necessary to fill the water into the kettle by the ordinary means of bailing. This bailing the author says he has long regarded as a disgrace to the art of mining, and so he devised what he calls the

"Pneumatic Water Barrel." It consists of a cylindrical vessel of sheet iron, 4ft. 2in. in dia., and 8ft. deep, closed at the top by an air-tight manhole door. The bottom is 5in. above the lower edge of the cylinder, and has a circular hole in it 18in. in diameter. This hole is closed by a faced valve of cast iron, mounted with a sheet of leather, capped and tightly clasped by an iron hoop. The valve is attached to a spindle by a ball and socket joint, by which it is kept in position, but allowed a certain amount of play so that it may readily accommodate itself to its seat. The cylinder is thus an air-tight vessel, the interior of which has communication with the exterior atmosphere only by means of a pipe, extending from close to the top of the cylinder in the inside, to the outside of the vessel half-way down. The outside end of the pipe is fitted with an instantaneous coupling identical with that used on the vacuum railway brake. In use the pneumatic water-barrel is lowered into the shaft till its lower edge is under water in the shaft bottom. The interior is put into communication with a condenser air-pump on the surface by attaching a flexible tube connected to the vacuum pipes in the shaft to the instantaneous coupling of the barrel. A vacuum equivalent to 20 to 22 inches of mercury is thus obtained inside the barrel, and the water rushes in through the bottom valve. A glass guage tube on the outside of the vessel shows when it is full. The tube is detached, and the signal given to raise the barrel. When it reaches the surface a bogie is run under it, and it is lowered on a conical block of wood, which raises the valve, and the water escapes. With 7500 gallons of water an hour thus raised, the rate of sinking was 4 yards a week. When the growth was only 500 gallons an hour, the progress attained was 6½ yards per week.

Two winding engines were erected and used in sinking—the principal engine for winding water and material from the shaft bottom, and an auxiliary for lower walling material, and latterly used to raise the water collected by a cistern, first at 135 yards, and afterwards at 190 yards deep. The latter engine was a compound one, built to the specification of the author, who wished to try experimentally a contrivance he had desired to meet the difficulties already experienced in applying compound engines to winding. His solution is to introduce a reducing valve between the feed pipe of the high pressure cylinder and the pipe connecting the high and low pressure cylinders with the object of maintaining the pressure in this connecting pipe when the engine is standing about equal to the average pressure therein when the engine is at work. The result has been entirely satisfactory. The guide ropes in the shaft are used to suspend the walling stage, which is always in the shaft, thus affording protection to the sinkers, and permitting the winding of water through a central opening 6 feet 6 inches square, while walling is going on. This stage is double the walling stage proper, having a roof 10 feet above it. The guide ropes are bound on drums of a steam crab, and can be wound or unwound simultaneously or separately. J. H.

Proceedings of the SOUTH WALES INSTITUTE of ENGINEERS.

AN EXPANSION JOINT FOR AIR, STEAM, AND WATER PIPES.

By C. T. HAIR. Vol. XVI. P. 189.

AN expansion joint which allows a deviation of 18in. from the straight in a 9ft. pipe must be of great use in many circumstances, and this is what is claimed for the joint described. It is secured by forming the expansion joint of a ring or cylindrical casting with internal projections of $\frac{5}{8}$in. or $\frac{3}{4}$in. round the ends. The external faces of these projections are formed to receive and fit an india-rubber washer of circular section. Two loose flanges, one to each end of the ring, are similarly faced on the side towards the ring. Between each of these flanges and the ends of the ring an india-rubber washer or ring is placed, and the flanges are tightly screwed together by bolts. The pipe ends within the expansion cylinder or ring require no special preparation, but may either be specially cast without flanges, or may simply have the flanges broken off; or indeed, two broken pipes may be used. J. H.

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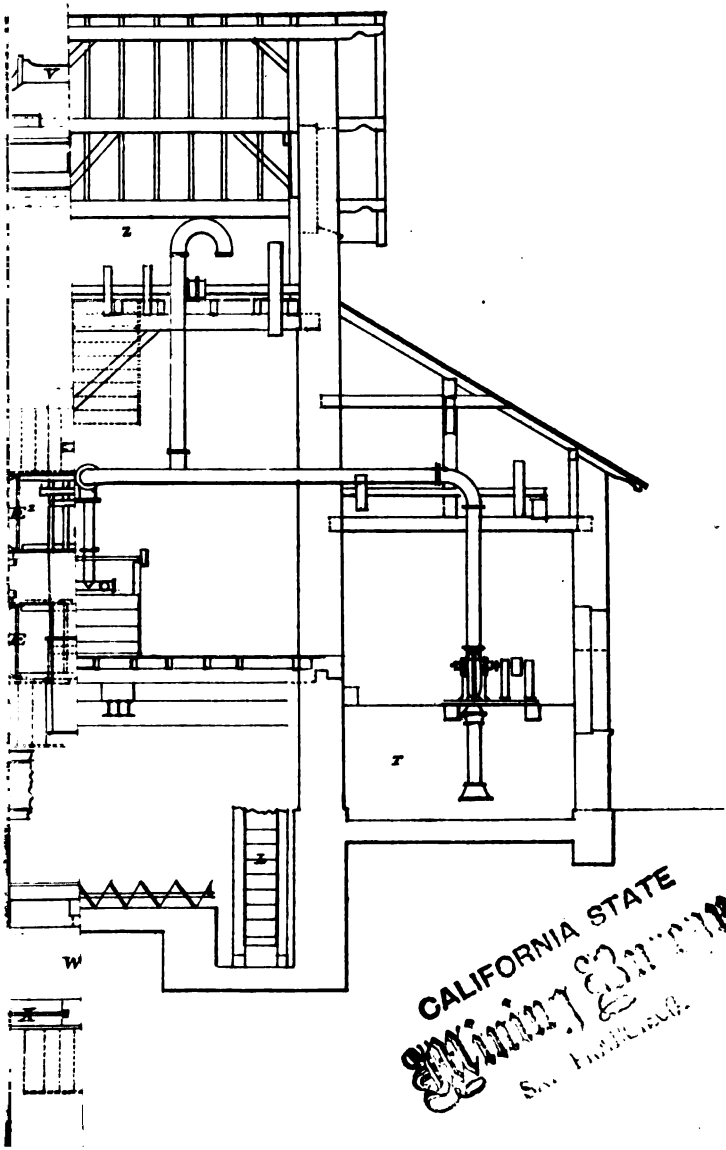

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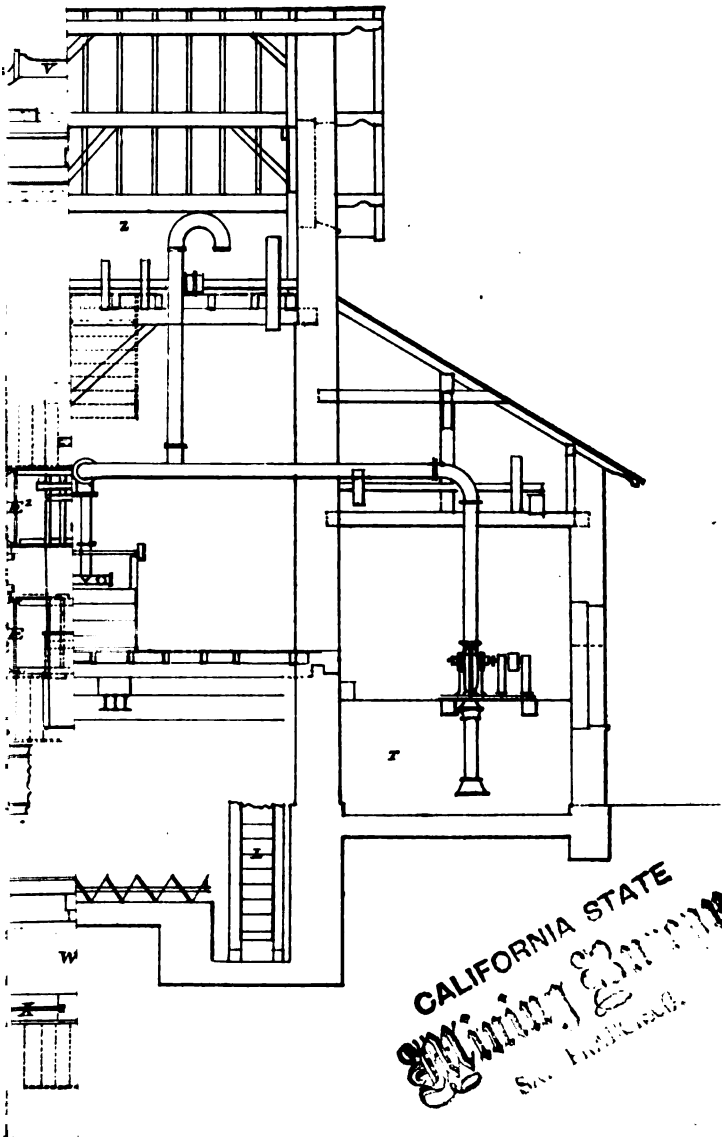

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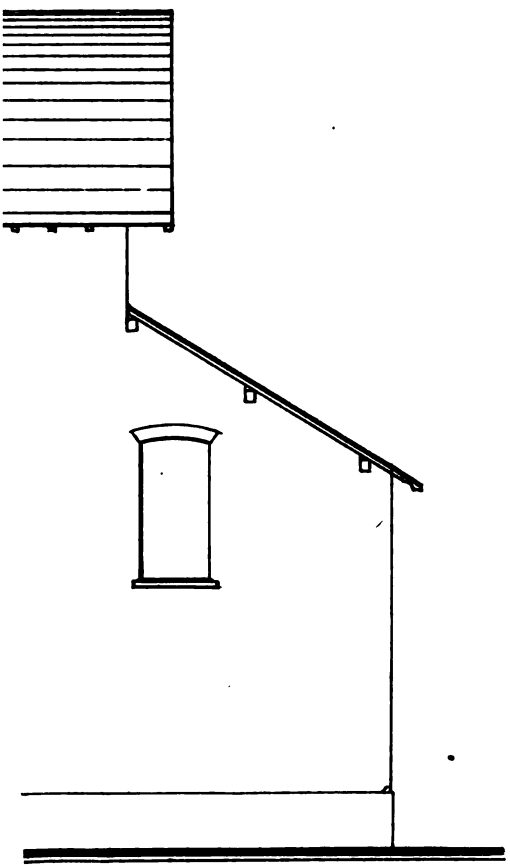

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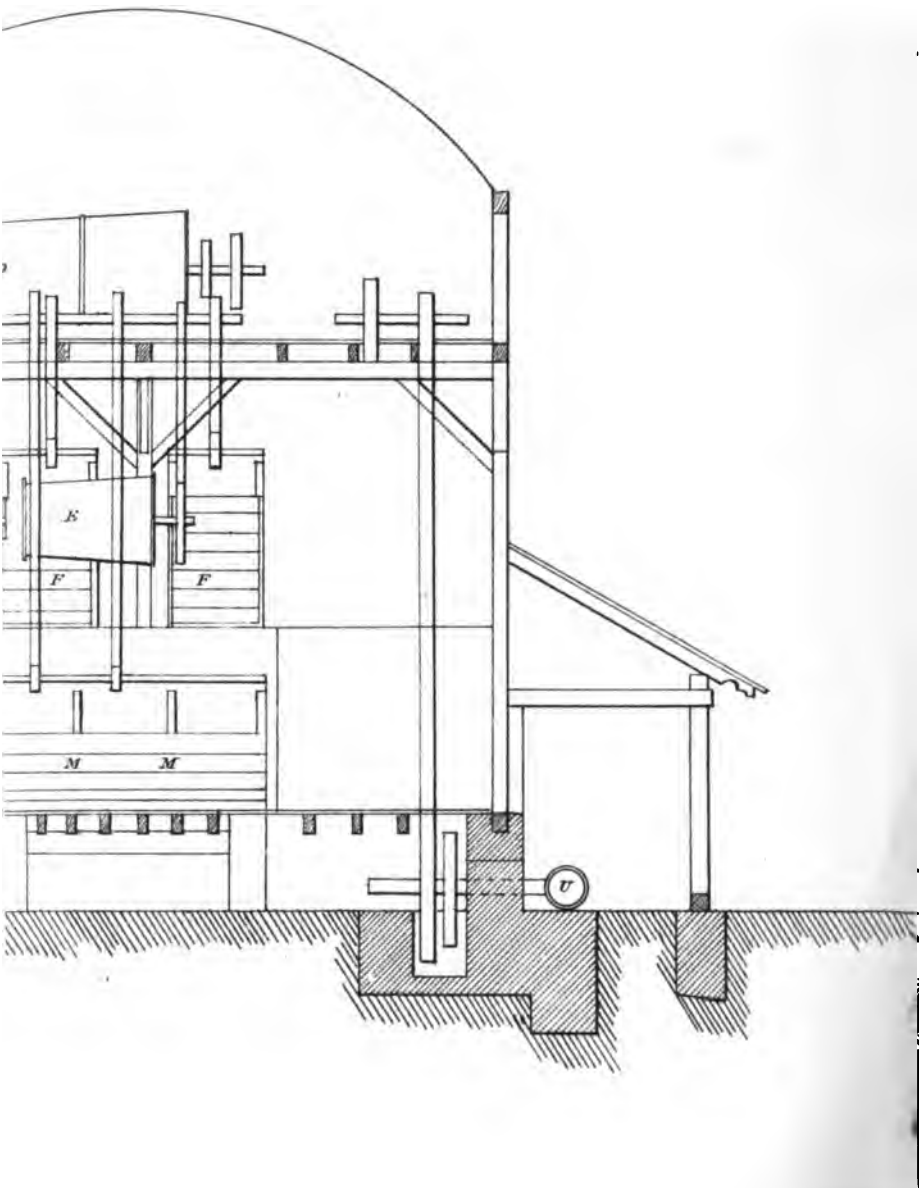

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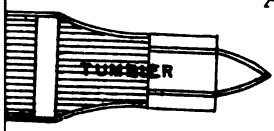

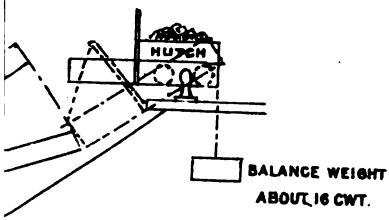

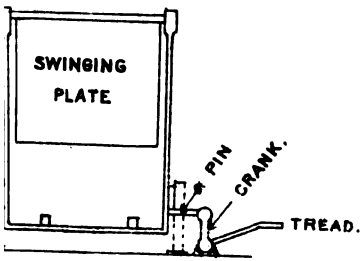

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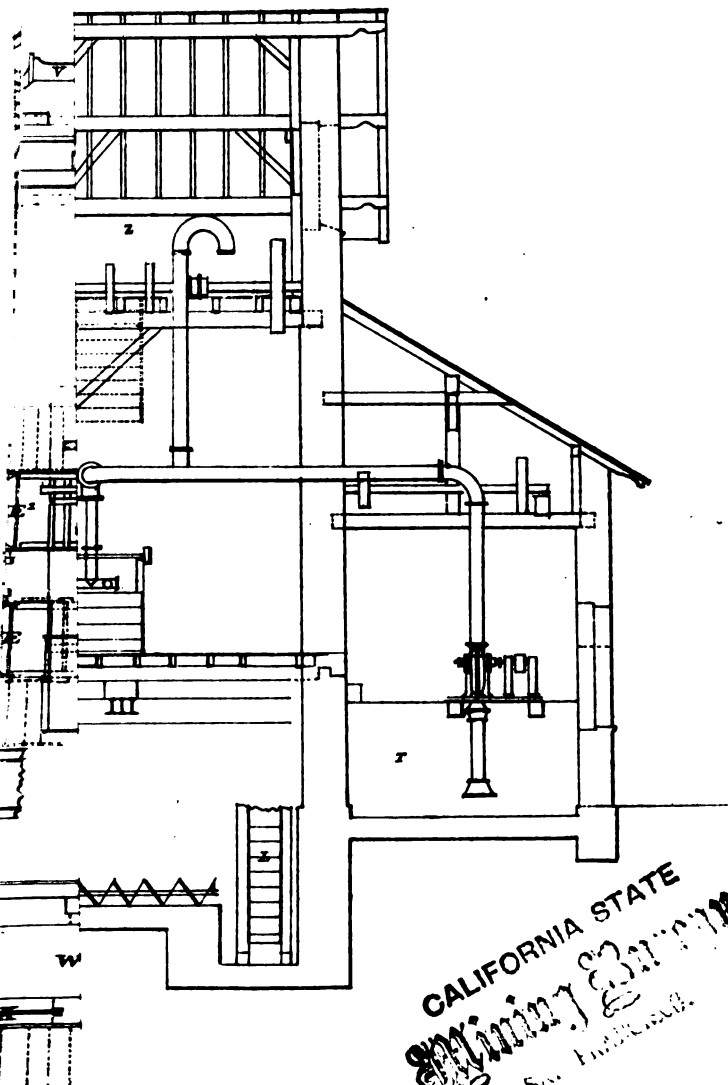

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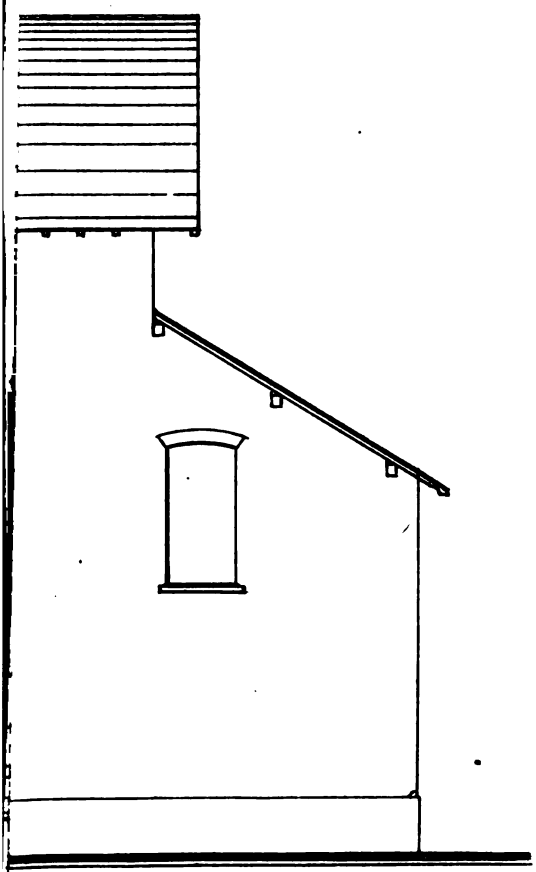

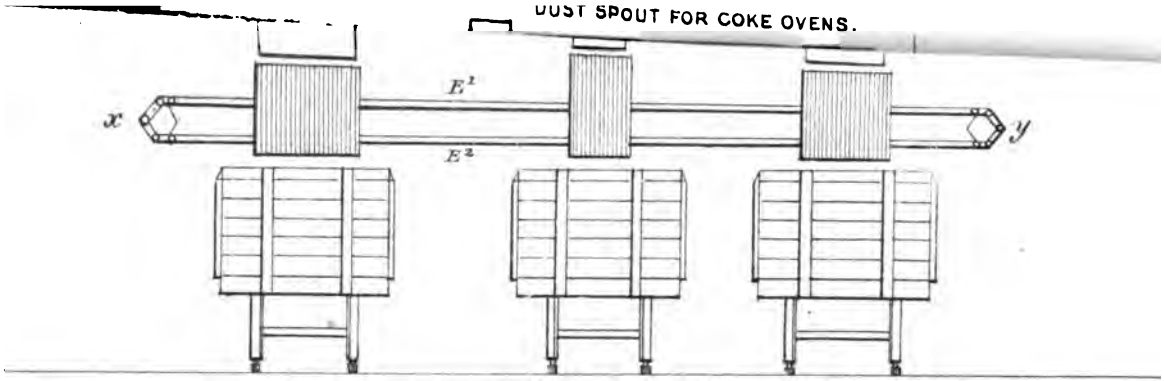

ELEVATION.

THE CROSS-CREEPER X TO Y IS FOR THE PURPOSE OF MIXING LARGE AND PEA-NUTS IN WITH THE COAL WHEN IT IS REQUIRED TO DO SO.

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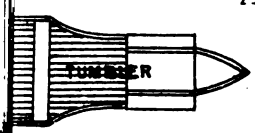
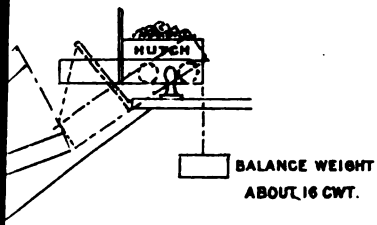
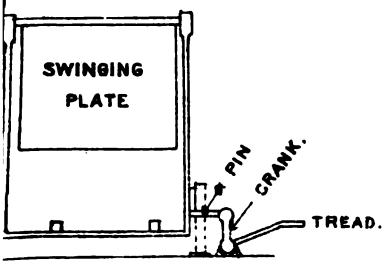
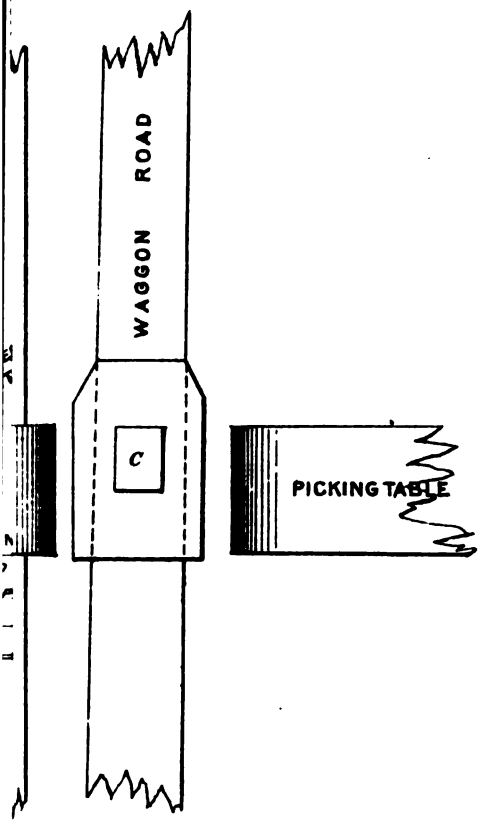






SAN FRANCISCO.

PLATE XII. VOL. XI.
M. I. S.



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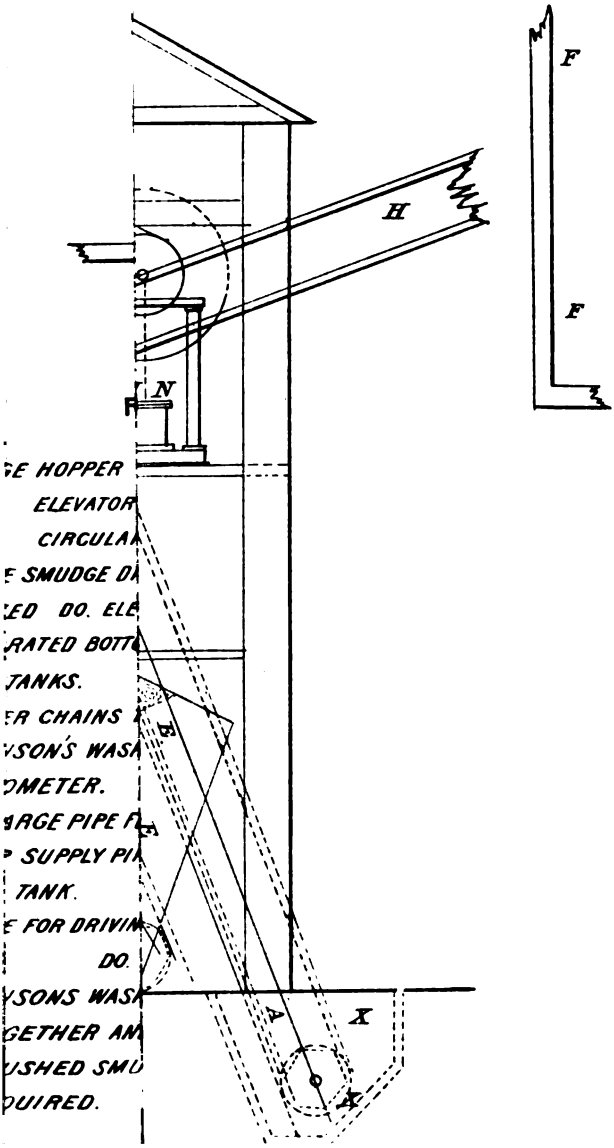
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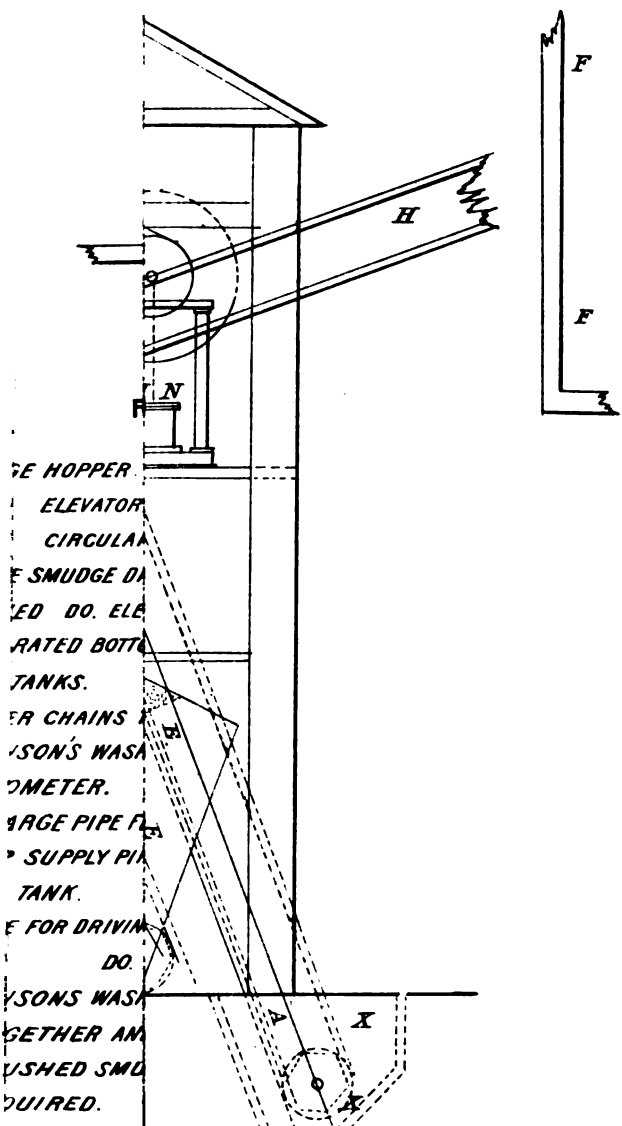
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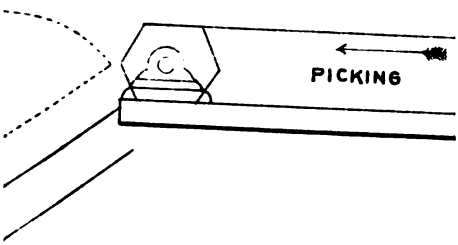
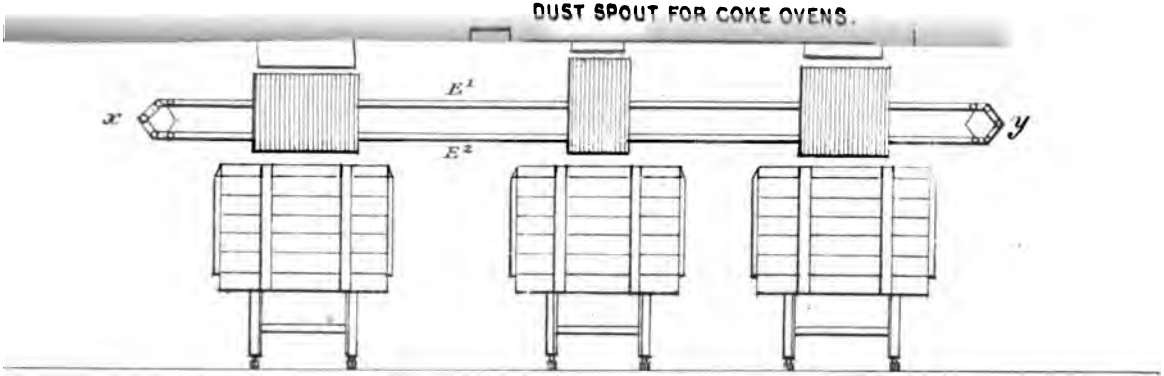


SIDE ELEVATION

DUST SPOUT FOR COKE OVENS.

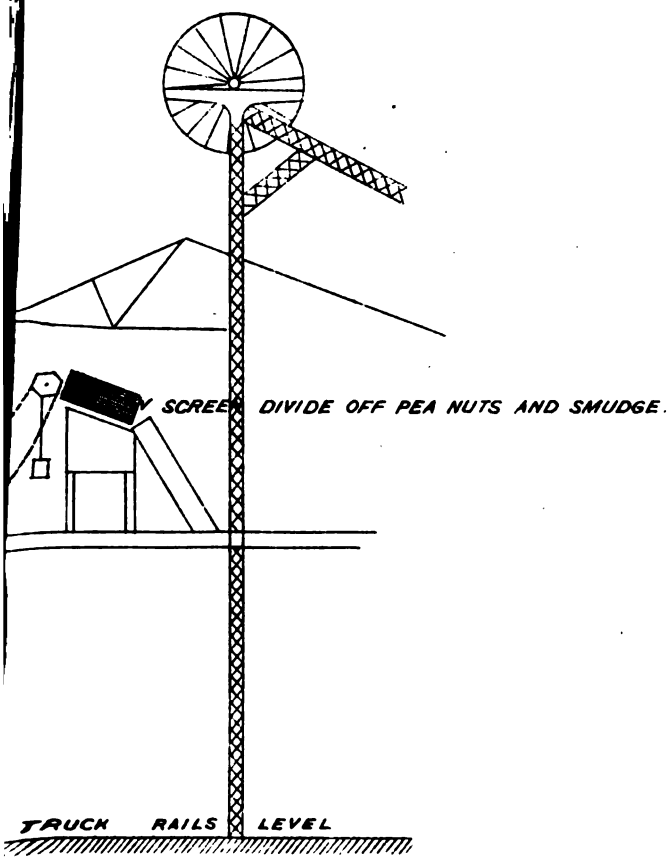


ELEVATION.

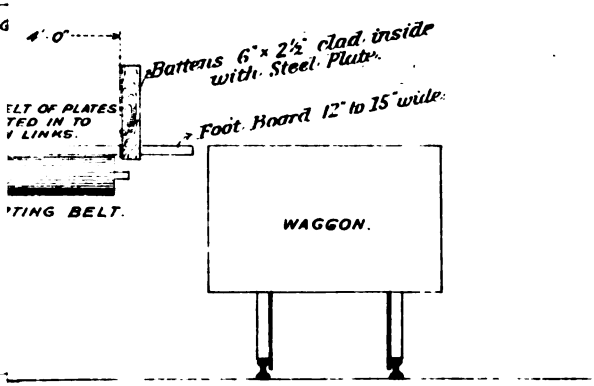
THE CROSS-CREEPER X TO Y IS FOR THE PURPOSE OF MIXING LARGE AND PEA-NUTS IN WITH THE COAL WHEN IT IS REQUIRED TO DO SO.

RATION AT NUNNERY COLLIERY.

Committee's Report.

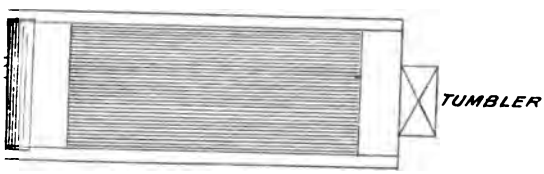


AT A. B.


4'. 0"
Battens 6" x 2½" clad inside with Steel Plate.
ELT OF PLATES
TED IN TO
LINKS.
Foot Board 12" to 15" wide.
TING BELT.
WAGGON.

:AFFOLD

which Coal lifted
s laid.



hich Coal lifted
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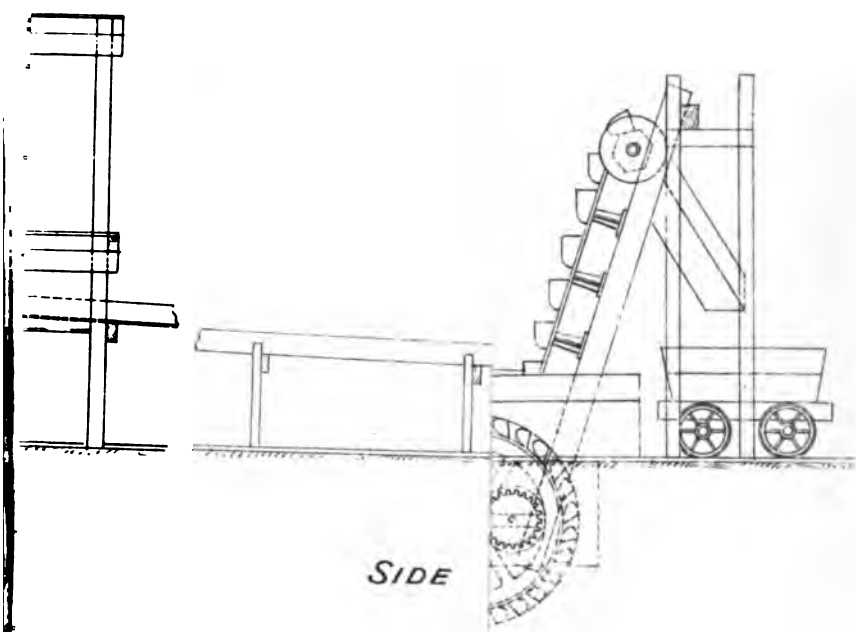
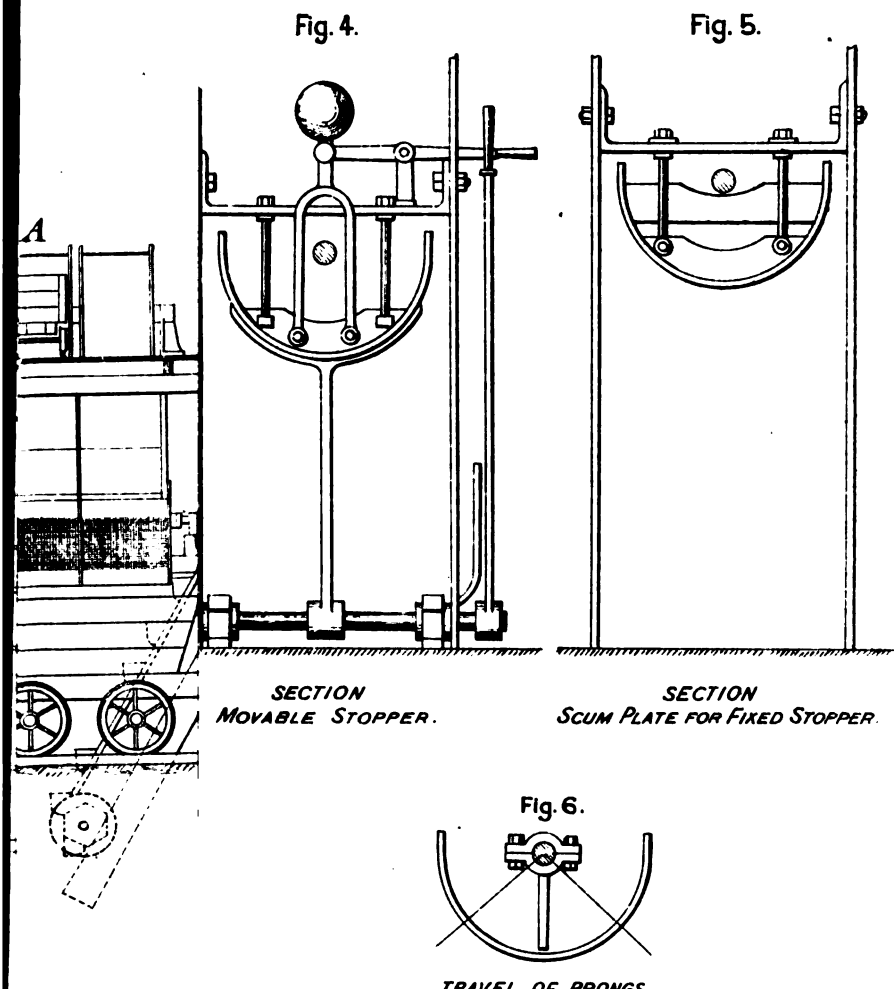

SIDE

T, FLIMBY

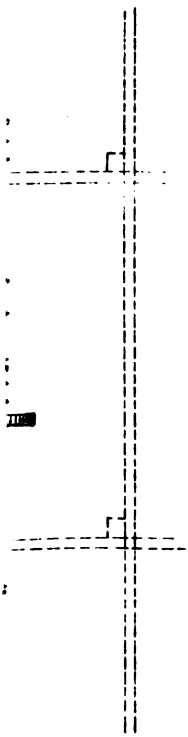
DETAILS OF BELL & RAMSAY COAL WASHER.

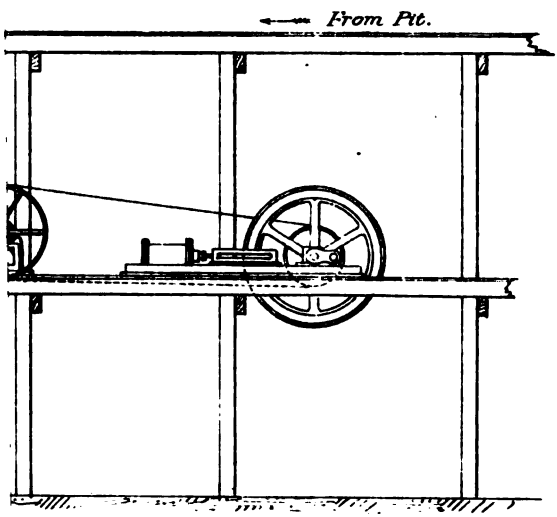
Scale ½" = 1 Foot.



AT ST. HELE

ittee's Report.





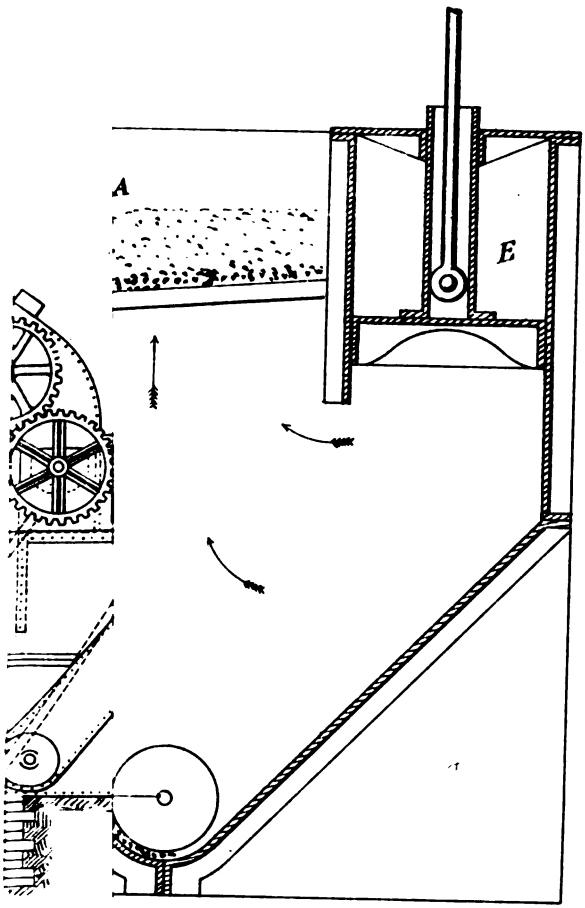
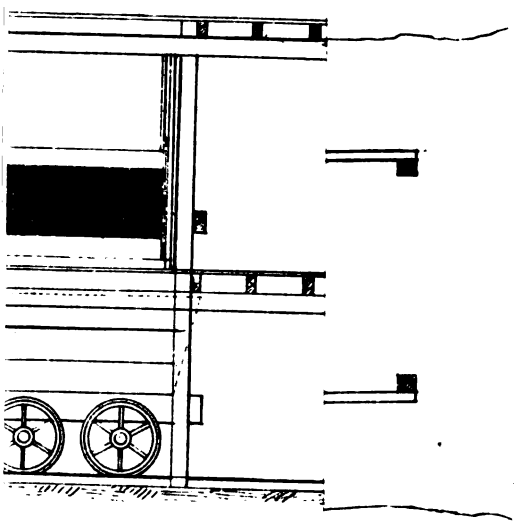


Fig. 2.

SIDE ECTION OF WASHER.

'NS AT WAULKMIL

'oal Cleaning Commi



ELEVATION.

CALIFORNIA STATE
LIBRARY
SAN FRANCISCO.

PLATE XXV, VOL XI.
M. I. S.

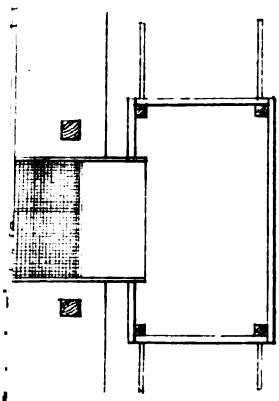
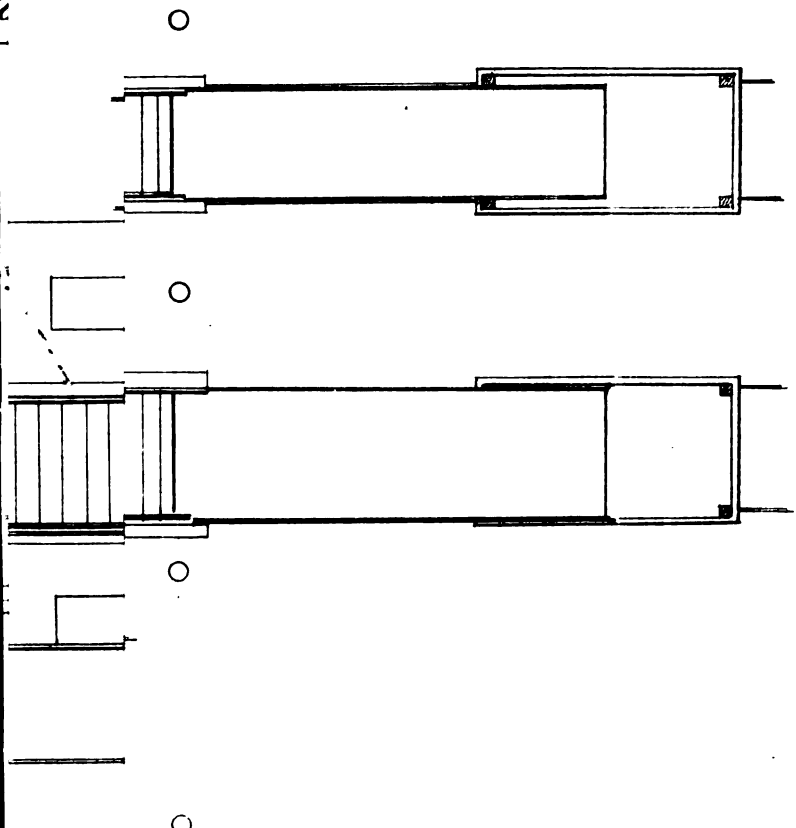


PLATE XXIX, VOL. XI.
M.I.S.



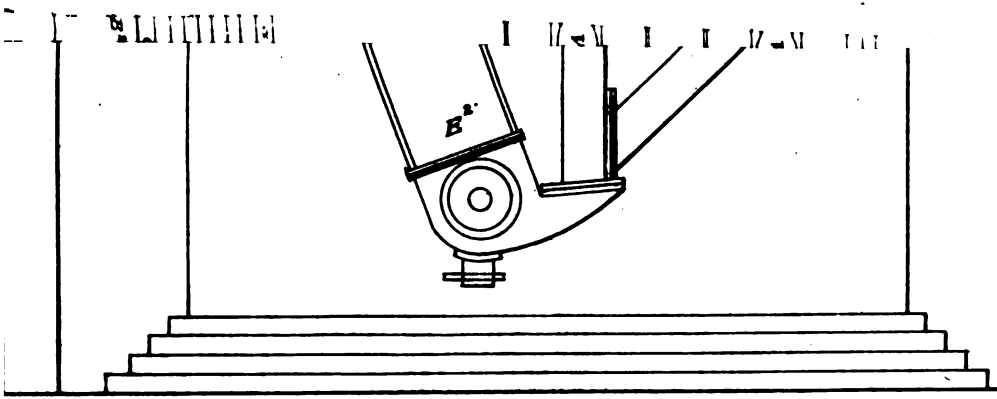


FIG. 3.

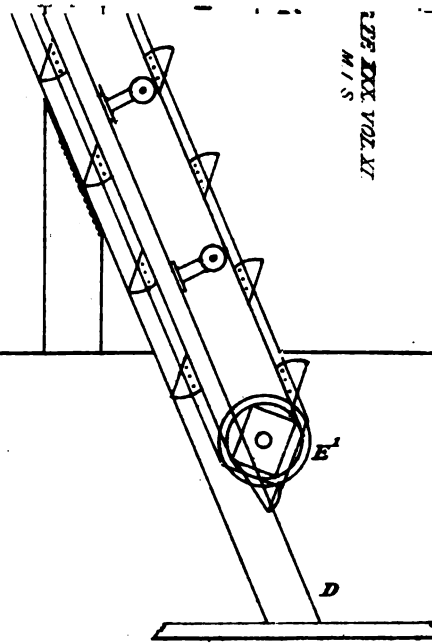


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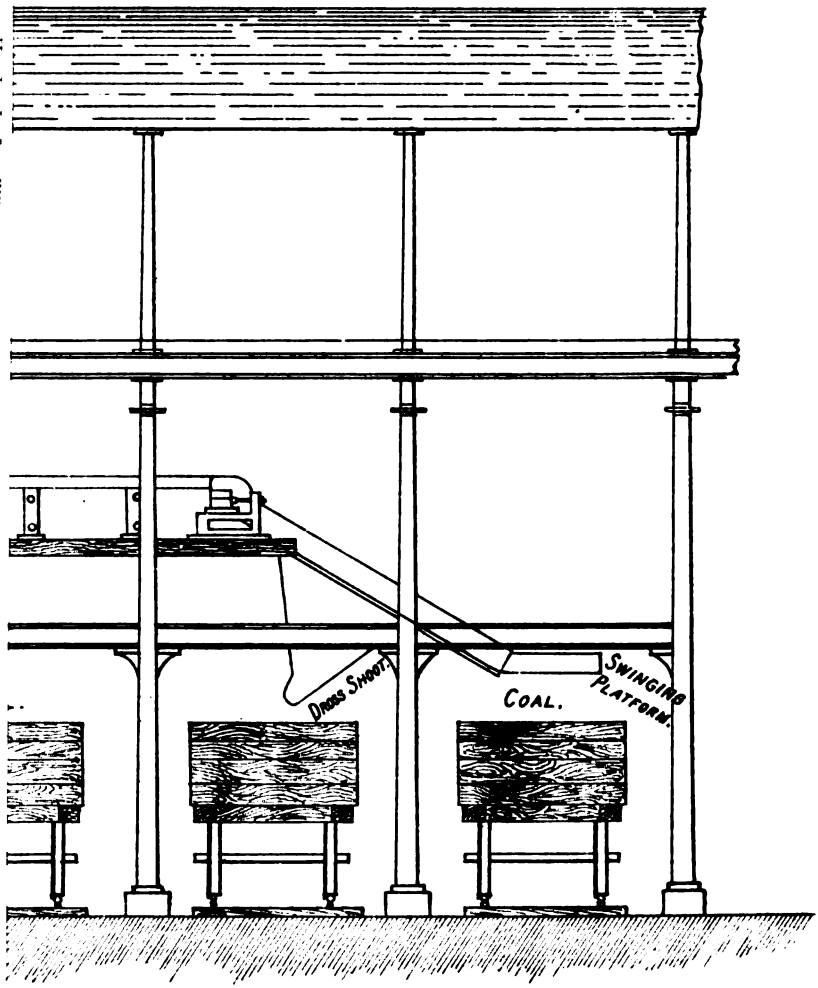
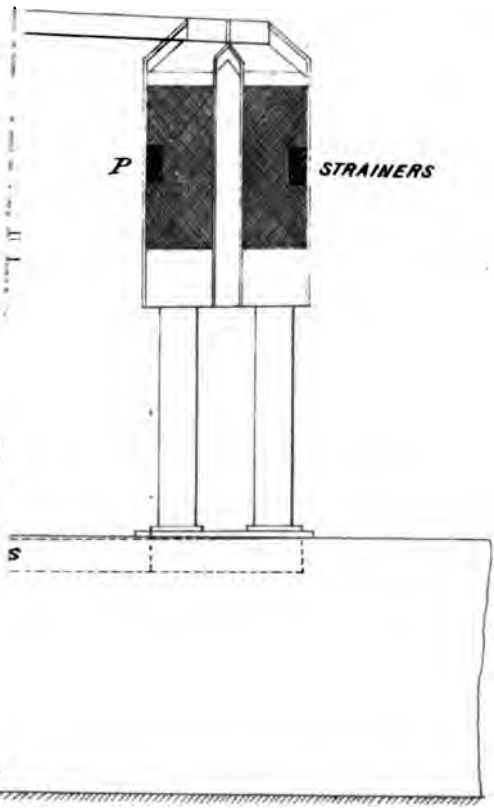
PLATE. XXXI. VOL. XI
M.I.S.


DROP SHOOT.
COAL.
SWINGING PLATFORM.

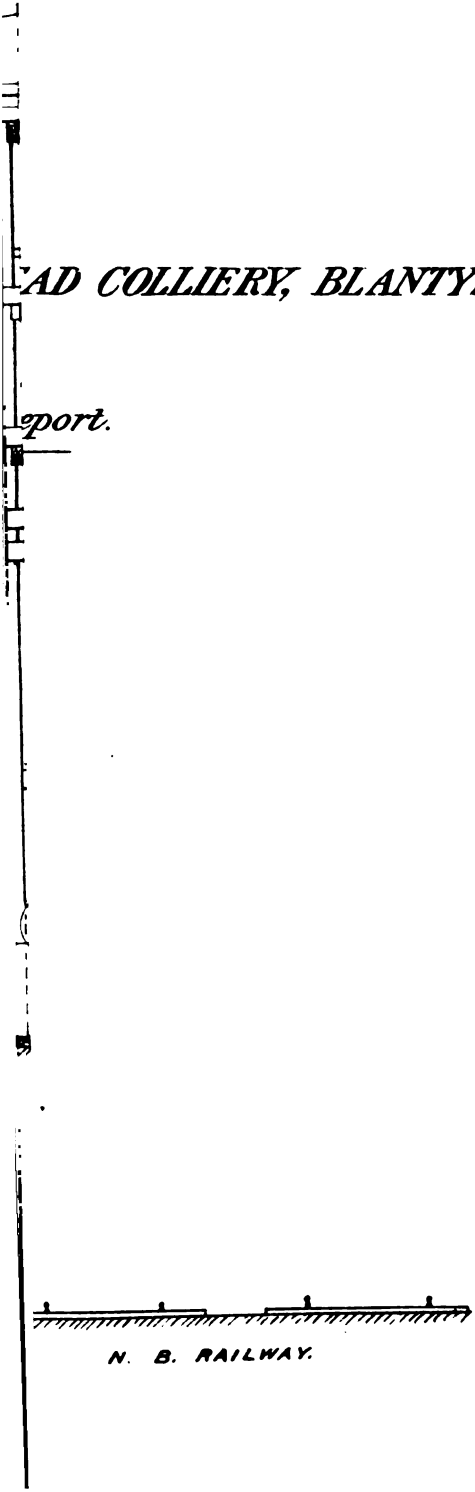
WASHING PLANT
ERY BLANTYRE.
1 Foot.

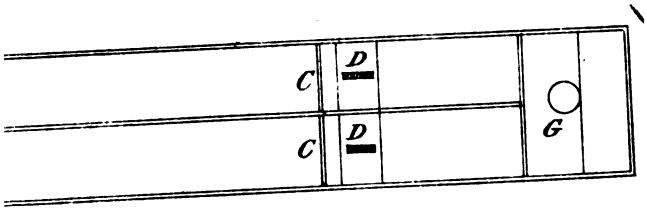
ng Committee's Report.



EAD COLLIERY, BLANTYRE.

eport.

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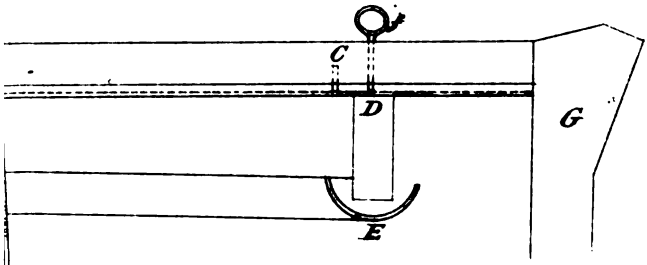
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PLATE XXXVII. VOL XI.
M. I. S.

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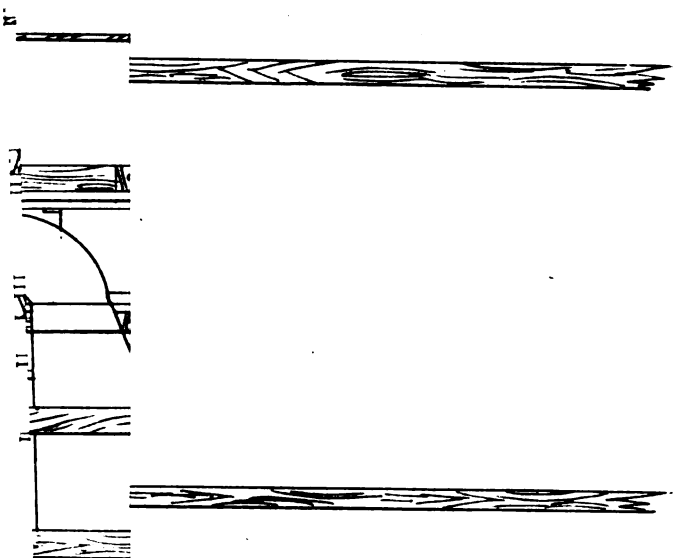
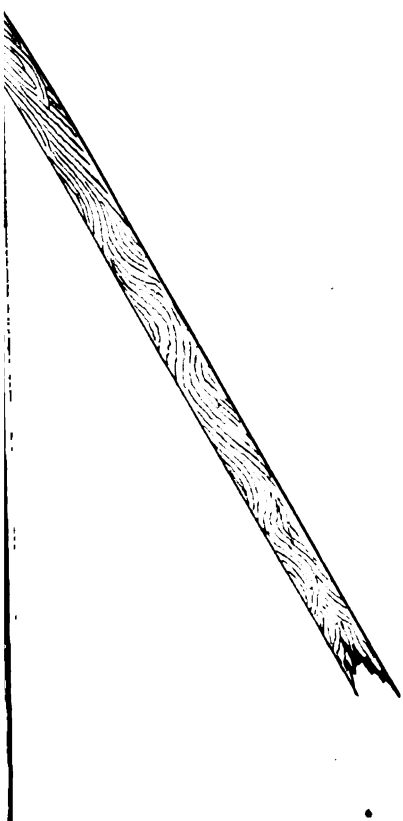
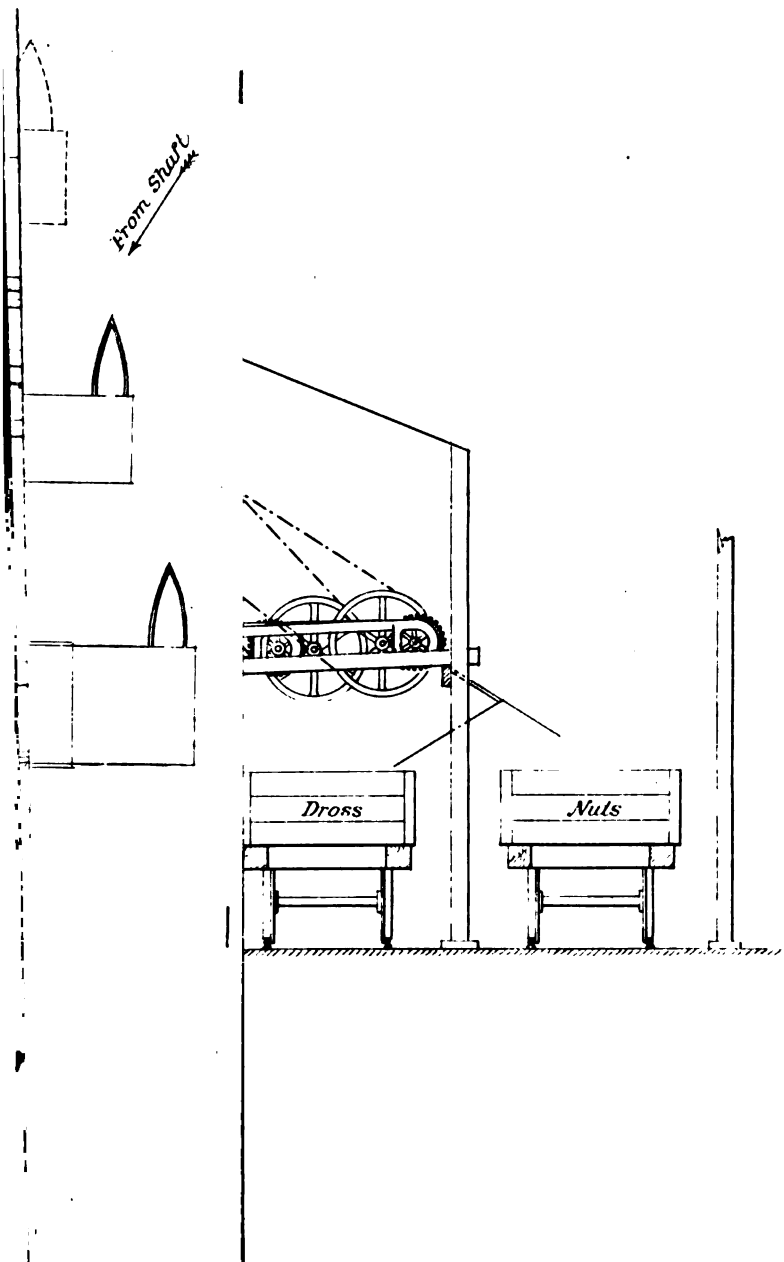


PLATE XXXVIII. VOL. XI.
M. I. S.

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Dross
Nuts

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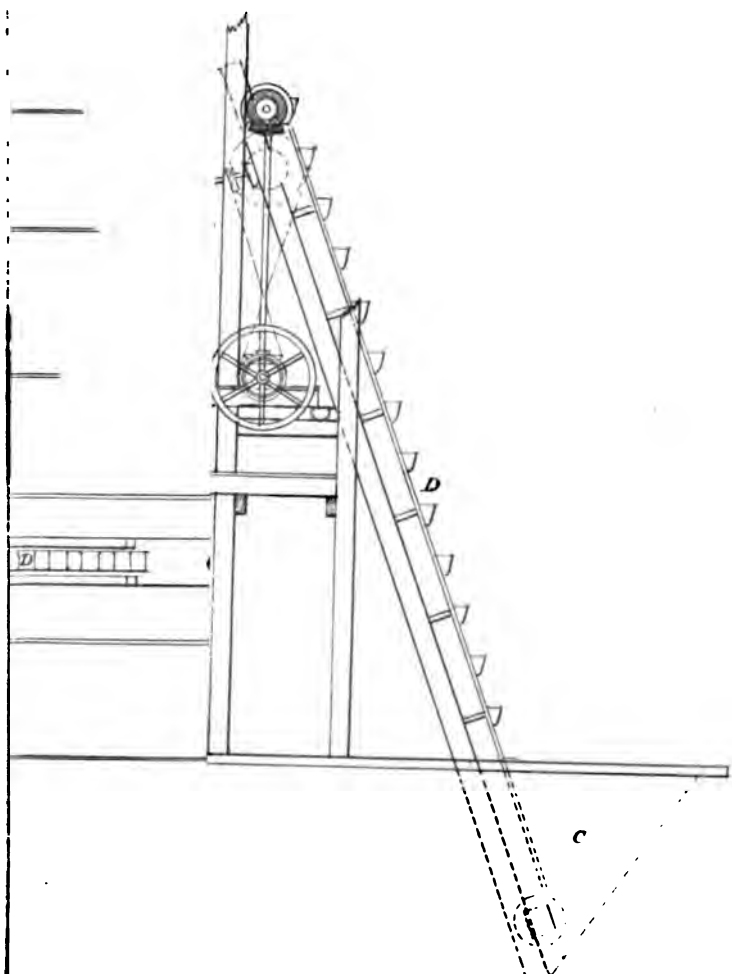
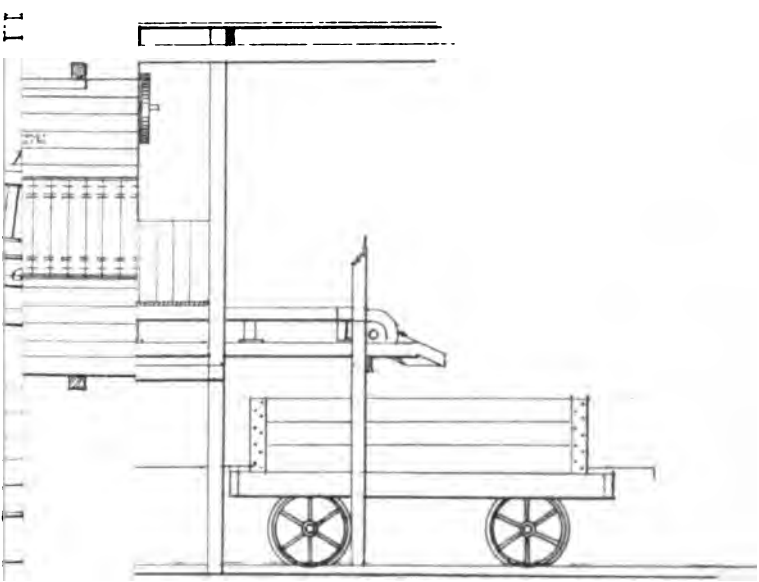
Cleaning Con





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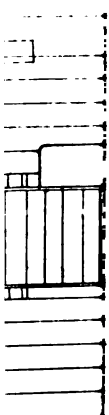

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